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# Editorial

## TO EGAS MONIZ

SCIENTIFIC progress, whether it be advancement in our fundamental knowledge or improvement in the diagnosis and treatment of disease, is often dependent upon the introduction and development of new techniques. Mankind, its scientists and its physicians, have often in the past been deeply in the debt of some original, pioneering mind which by the invention of new methods has paved the way for great progress. In the fields of neurology and psychiatry we are particularly beholden to one of the most challenging, independent and resourceful physicians of our day—Egas Moniz of Lisbon. Through the introduction of *Cerebral Angiography* in 1927 and its subsequent development in collaboration with Almeida Lima he opened to us a new avenue of approach to a more thorough comprehension of the cerebral circulation and to the study and treatment of various intracranial disorders, particularly neoplasms, aneurysms and other congenital vascular anomalies. Since this innovation by Egas Moniz there have been several valuable modifications which have enhanced the usefulness of cerebral angiography. Quite independently Loman and Meyerson in Boston in 1936 and Kentaro Shimidzu in Japan in 1937 advocated the percutaneous puncture of the carotid artery instead of the open operation.

Visualization of the carotid circulation supplies information about only a part of the vascular supply of the brain. In order that the vertebral, the basilar and the posterior cerebral arteries might be visualized Egas Moniz advocated the retrograde filling of the vertebral artery through the open wound. However, this was never a wholly satisfactory procedure. Several operators had accidently punctured the vertebral artery when seeking for the carotid by the percutaneous method. Taking advantage of these experiences several surgeons began to puncture the vertebral artery deliberately. Takahashi, a pupil of Shimidzu, developed a rather difficult percutaneous method in 1940 which did not meet with widespread acceptance. The simple direct method, now in common use, of puncturing the vertebral artery as it passes from the foramen in the transverse process of one cervical vertebra to the next was discovered by Lindgren in Sweden in 1947. Unfortunately the knowledge of Lindgren's valuable discovery was not widely disseminated. In 1948 this same method was independently developed and thoroughly publicized by Sugar, Holden and Powell of the University of Illinois in Chicago.

The most recent advance in cerebral angiography has been the development of several different methods for the taking of serial pictures, demonstrating the various degrees of filling and visualization of the arterial, capillary and venous systems of the brain. None of these methods has as yet been thoroughly perfected although several show great promise. There

is undoubtedly much advantage in being able to study the various parts of the cerebral circulation, as compared with simple cerebral arteriography.

These improvements in the technique of cerebral angiography have greatly increased its use and enhanced its usefulness. Many problems, however, still remain to be solved. Chief of these is the development of a perfect contrast medium which will be readily available, reasonable in cost, provide excellent visualization, be non-irritating to the vascular walls and generally innocuous.

With increasing experience, knowledge as to the normal and abnormal angiographic patterns and their significance is steadily being accumulated and published. The hope that by angiography it might be possible to determine the nature of various intracranial neoplasms has been only partially realized but its complete achievement is still a goal to be sought.

Cerebral angiography has made it possible to plan and execute suitable treatment for various intracranial vascular lesions. However, only a beginning has been made in this therapeutic field. These lesions still remain serious and carry with them a high mortality and morbidity. Certainly it is reasonable to believe that with further study of the cerebral circulation, increased utilization of cerebral angiography and continued clinical experience with lesions of this type our ability to deal with them successfully will steadily improve.

PAUL C. BUCY, M.D.

# PATHOLOGICAL ANATOMY AND ANGIOGRAPHY OF INTRACRANIAL VASCULAR ANOMALIES*

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(Received for publication June 19, 1950)

DORCUS HAGER PADGET[15] has pictured and described the changes in development of the cranial arteries of the human embryo in a beautiful monograph which is an amplification of the chapter written for Dandy's book[8] on intracranial aneurysms. The information contained therein renders more comprehensible some of the anomalies of the adult cerebral vascular tree. Indeed, Dandy[8] held that there could be but one explanation of aneurysms of the congenital type—that they have their origin in defects incident to the resolution of the early vascular bed. The alternative hypothesis is that of Forbus,[9] which ascribes the formation of aneurysms to persistent pressure against the weak point of bifurcation of an artery—where the media may be defective. That this has not been a completely satisfactory explanation was pointed out by Richardson and Hyland.[16] They felt it necessary to assume that although structural defects predispose and determine the sites of berry aneurysms, some additional, acquired lesion was required to weaken the elastica to cause the outpouching. Bremer[3] has given explanations for the lack of development of arterial walls in outpouchings, based on the lack of pulsation which induces developing arteries to form walls to contain the pulsation, or to degeneration of the walls when they no longer function in this manner. He believes that rapid stretch at bifurcations of the middle cerebral from the carotid, and of the posterior communicating arteries at the basilar could contribute to aneurysmal formation since muscularis appears latest in the fork of such angles. Other aneurysms not at forks might be derangements of embryonic vessels (which develop before the muscular coats are laid down). It appears obvious that a more careful consideration of the embryologic features of the vessels of the brain may give better understanding of intracranial vascular anomalies. Mrs. Padget has graciously permitted me to reproduce some of the drawings from her monograph.

## ANEURYSMS

Fig. 1 shows the mode of formation of the basilar artery from the two longitudinal neural arteries under the neural tube in the early embryo (Congdon,[6] Padget[15]). At the line of fusion one might expect medial defects to occur, and such opposing deficiencies have been described in the basilar

* Presented at the meeting of the Harvey Cushing Society, Colorado Springs, Colorado, April 16, 1950.

artery of the child of 13 weeks whose case was reported by Forster and Alpers.[10] The aneurysm in this case was at the bifurcation of the basilar into the posterior cerebral arteries. An exactly similar bulge was depicted in a human embryo of 42 weeks by Bremer[3]—surely the earliest "berry aneurysm" known! The adult counterpart of this type of aneurysm is shown in Fig. 2. Since these long vessels fuse by growing toward one another and by capillary connections which later disappear, it would not be difficult to assume that relicts of these vessels could expand into other basilar aneurysms not at the bifurcation (Figs. 3 and 4).

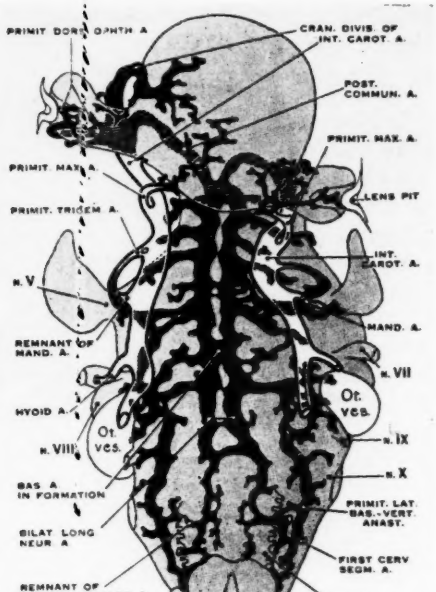


FIG. 1. The cranial arteries in a 12.5 mm. embryo (Fig. 5b of Padget[15]).

Another primitive vessel, the primitive vertebral-basilar anastomosis, is shown in Fig. 1. This disappears when the vertebral arteries form by fusion of cervical segmental arteries and come to join the basilar artery in the midline. Persistence of such an artery or its early branches might well account for the location of an aneurysm well to one side of the basilar artery, such as has been described by Schwartz[17] in his case of successfully treated posterior fossa aneurysm. It is also probably some remnant such as this which accounted for a peculiar vessel which compressed the last four cranial arteries lateral to the medulla oblongata, in the man whose arteriogram is shown in Fig. 5. This should be compared with the normal axial vertebral angiogram shown in Fig. 6.

The primitive trigeminal artery (Fig. 1) is the earliest communication between the carotid and the basilar systems. With establishment of the posterior communicating artery (which in the embryo is one of the two basic termini of the internal carotid artery), this vessel dwindles and disappears. Occasionally it persists in the adult as a large artery passing between the internal carotid artery in the cavernous sinus and the basilar artery in the region of the trigeminal nerve roots. In this event, the vertebral artery on that side (or both vertebral arteries) may be considerably reduced in size (Sunderland,[21,22] Altmann[1]). When it does not persist, there may arise

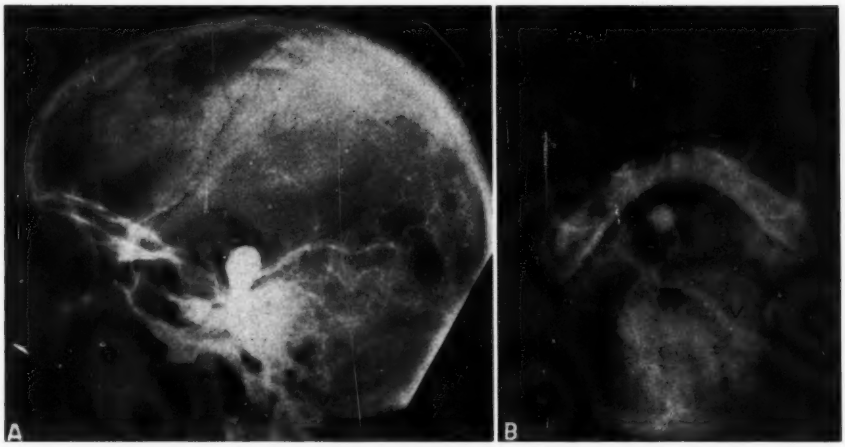


FIG. 2.* Aneurysm of basilar artery at bifurcation. (A) Lateral angiogram. (B) Submental-vertex (axial) view.

at its site of embryonic origin, an aneurysm (be it by persisting medial defect not at a bifurcation, or by nubbin of residual vessel). This is the aneurysm of the cavernous portion of the carotid artery, an example of which is shown in Fig. 7. This area may also be the weak spot which predisposes to traumatic or "spontaneous" rupture of the carotid artery in the formation of a carotid-cavernous fistula. Some such explanation is necessary to understand why the normally thick-walled strong carotid artery should break just here, surrounded by a much thinner-walled sinus containing venous blood. Figs. 8 and 9 show lateral and anteroposterior views of arteriograms in patients with such fistulae. The latter film demonstrates reflux into the fistula from injection of the contralateral carotid artery, a mechanism which often requires that a clip or ligature be placed intracranially on the internal carotid artery in addition to tying off the artery in the neck. If the clip is placed intracranially distal to the exit of the ophthalmic artery, the fistula may continue to be fed from the external carotid artery. How this comes about is best understood from another diagram (Fig. 10) from Padget.[15]

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* Abbreviations used in the figures are as follows: ac., anterior cerebral artery; an., aneurysm or anomalous vessel; an. v., anomalous vein; a.v., anomalous vessel or arteriovenous malformation; b., basilar artery; c.s., cavernous sinus; f.a., false aneurysm; i.c., internal carotid artery; ic. v., internal cerebral vein; mc., middle cerebral artery; ov., ophthalmic vein; p. cblr., posterior inferior cerebellar artery; p. cer., posterior cerebral artery; p. comm., posterior communicating artery; th., thalamic vessels; v., vertebral artery.

*Note:* Figs. 16, 23, 24, and 29 are from patients at the Illinois Neuropsychiatric Institute whose cases have been reported by Green and Arana.[11] Figs. 2 and 8 are from patients whose cases were reported by Sugar, Holden and Powell.[19] Fig. 19 is from a patient whose case was reported by Sugar and Tinsley.[20]

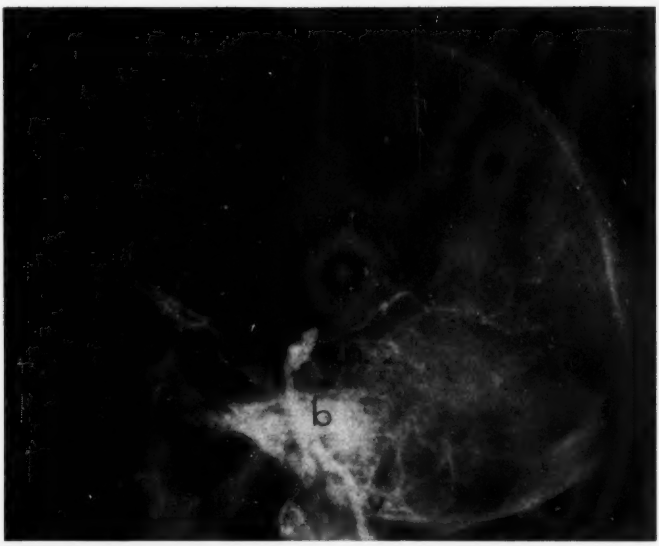


FIG. 3. Aneurysm of posterior cerebral-basilar area.

FIG. 4. Aneurysm of basilar artery or branch.

There arises from the second gill arch artery a vessel which ultimately becomes the hyoid-stapedial artery. The stapedial portion grows up to the

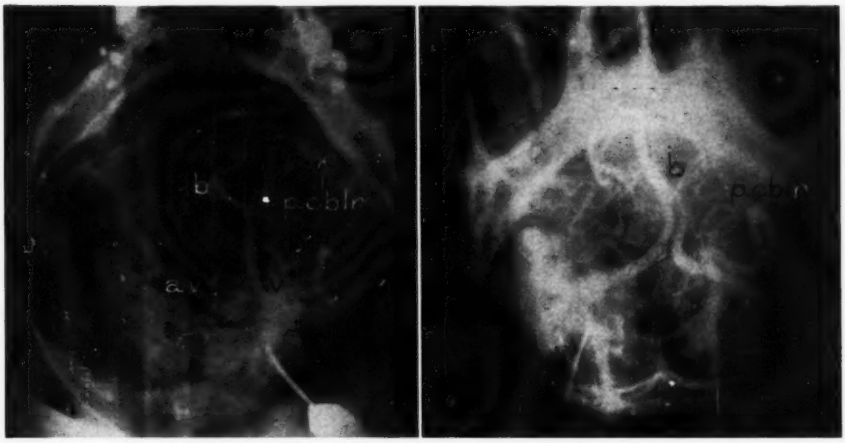

FIG. 5 (*left*). Anomalous branch of vertebral artery (axial view).

FIG. 6 (*right*). Normal vertebral artery injection (axial view).

eye and supplies the orbit, fusing with branches of the ophthalmic artery. Later, the orbital branches are taken over by the internal maxillary division of the external carotid artery, and the stem of the stapedial artery ordinarily disappears leaving only a small hyoid remnant, the carotico-tympanic branch

FIG. 7. Aneurysm of cavernous portion of internal carotid artery.

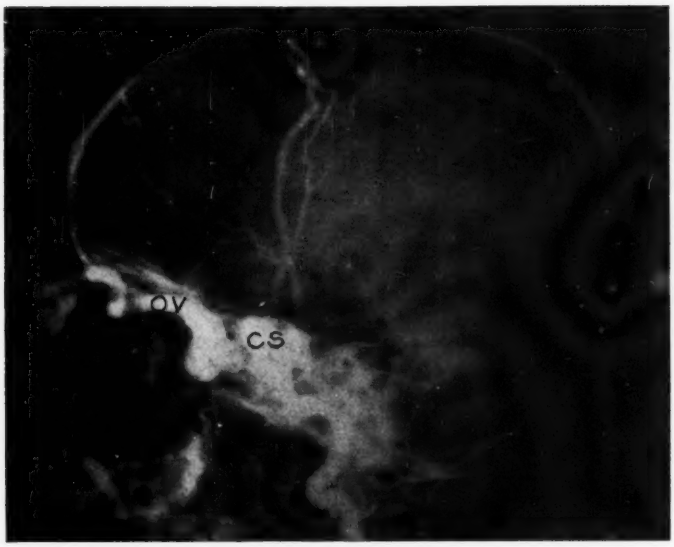


FIG. 8. Carotid cavernous fistula.

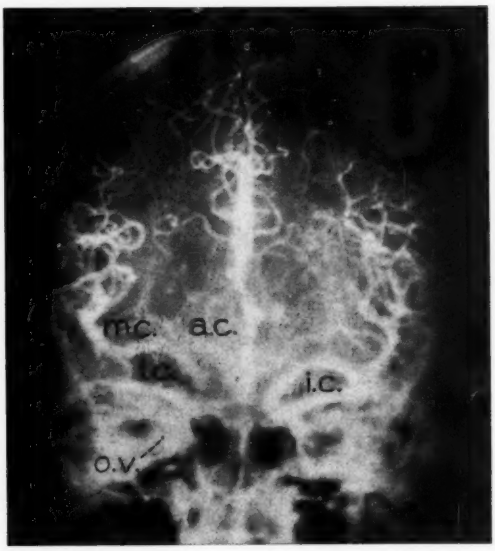


FIG. 9. Carotid-cavernous fistula (injection made on left). Note filling of intracranial portion of right internal carotid artery and opacity (ov.) in right orbit, lacking in left orbit.

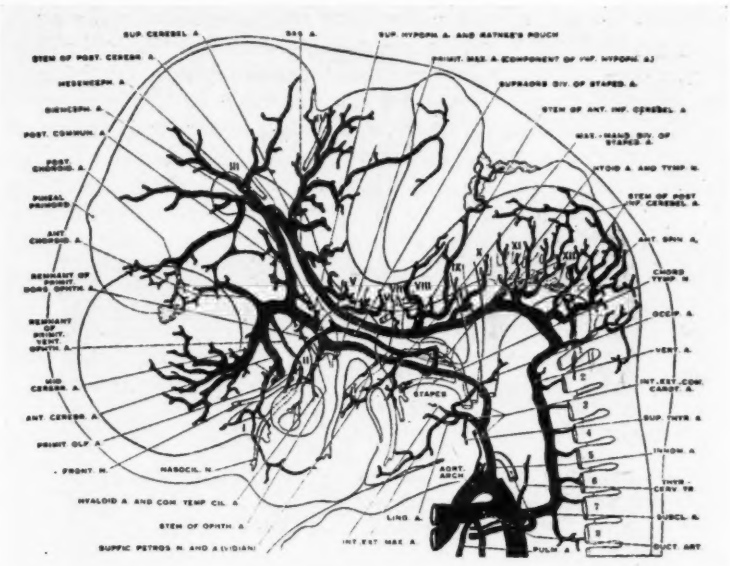


FIG. 10. The cranial arteries in an 18 mm. embryo (Fig. 7a of Padget[15]).

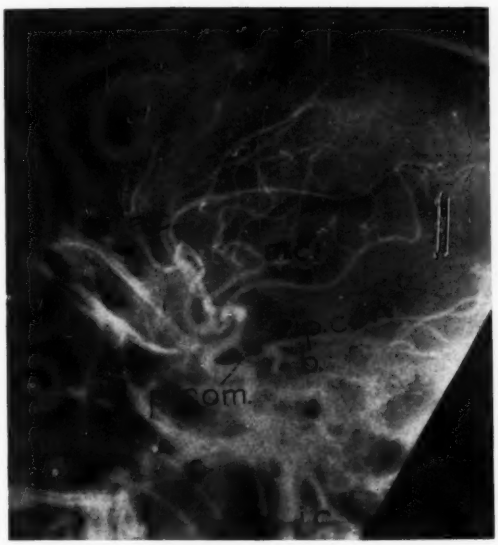

FIG. 11. Normal internal carotid angiogram, showing filling of the posterior communicating, posterior cerebral and beginning of basilar arteries.

of the adult. Occasionally, the stapedial artery persists in the adult (Altmann[1]). Eventually, the ophthalmic artery takes over the orbital branches, but the communications with the internal maxillary may persist, and allow transfer of blood from the external carotid artery to the intracranial portion of the internal carotid artery. Such pathways may be more effective than the posterior communicating artery in supplying the intracranial carotid circulation, as in cases of bilateral occlusion of the internal carotid artery by endarteritic processes. Angiograms of the connections between

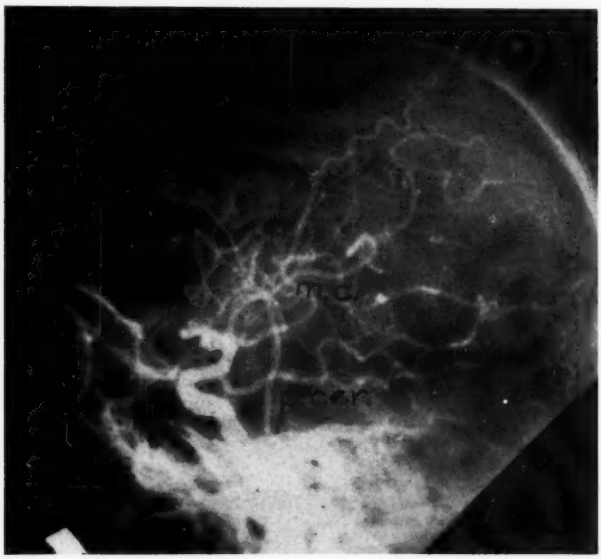

FIG. 12. Internal carotid angiogram showing origin of the posterior cerebral artery from the carotid artery, and apparent absence of the anterior cerebral artery.

ophthalmic (internal carotid) and lacrimal (external carotid) arteries have been shown by Marx.[13]

Another interesting feature of growth of the circle of Willis is the large size of the posterior communicating artery in the embryo, arising directly as a division of the internal carotid artery. It usually dwindles to a small connection (Fig. 11) with the posterior cerebral artery which typically comes off the basilar artery in the adult. The communicating vessel may, however, persist as the main stem of the posterior cerebral artery which then arises from the internal carotid artery (Fig. 12). This figure, incidentally, shows one of the difficulties in interpretation of angiograms: there is no anterior cerebral artery shown here, although the very next injection of contrast material for an anteroposterior view (Fig. 13) shows the anterior cerebral quite well. Similarly, the statement (based on angiography) that

the most common intracranial arterial anomaly is the origin of both anterior cerebral arteries from one internal carotid artery must be refused acceptance. Fig. 14 shows such bilateral filling from one side, and the injection made on the opposite side (Fig. 15) appears to confirm the anomalous origin. However, the next injection did show filling of the anterior cerebral on the second side, so one must assume that failure of filling, unilateral or bilateral filling of the anterior cerebral arteries may depend wholly on the relative intravascular pressures on the two sides at the time when the contrast medium reaches the anterior communicating area.

FIG. 13. Anteroposterior carotid angiogram showing presence of anterior cerebral artery (same patient as in Fig. 12).

The ophthalmic artery has an origin of interest in relation to vascular anomalies. The eye is first lateral to the brain proper and is supplied by primitive ventral and dorsal ophthalmic arteries. The ocular supply of these vessels is taken over by the definitive ophthalmic artery, which starts near the bifurcation of middle and posterior cerebral arteries and wanders down the internal carotid by a series of anastomotic loops to its definitive position *under* the optic nerve. The ventral and dorsal ophthalmic arteries (Fig. 10) usually disappear, but remnants may be responsible for lateral and medial aneurysms of the internal carotid artery between the ophthalmic and posterior communicating vessels of the adult. One posterolateral aneurysm in this region is shown in Fig. 16. Similar elongated aneurysms have been termed "arteriosclerotic" presumably because they are not typically spherical (saccular). Actually, such elongated masses may be produced by ruptures of the ends of vestigial vessels: I have recently operated upon two of these in which there was a definite vessel arising from the internal carotid artery, pointing laterally and ventrally; it could not be distinguished, grossly, from any normal branch of the carotid artery. The end, however, consisted only of blood clot, which had become adherent to the oculomotor nerve and produced oculomotor palsy. The more posteriorly pointing aneurysm shown (Fig. 17) is of the type commonly ascribed to blowing-out at a medial defect at the branching of the posterior communicating artery from the carotid. Actually, there are numerous embryonic vessels in this region: some later pass to the hypophysis, and others may give rise to this type of aneurysm. That such anomalous branches of

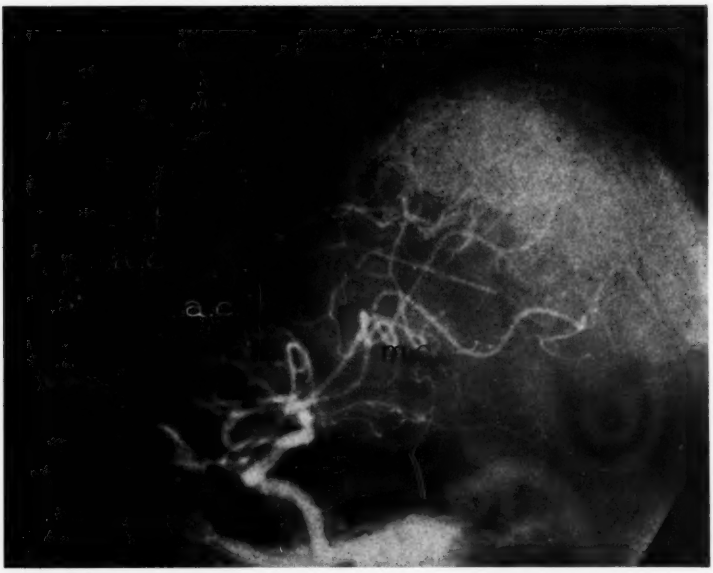


FIG. 14. Lateral carotid angiogram (injection into right internal carotid artery), showing filling of both anterior cerebral arteries.

FIG. 15. Lateral carotid angiogram (injection into left internal carotid artery) showing apparent absence of anterior cerebral artery (same patient as in Fig. 14).

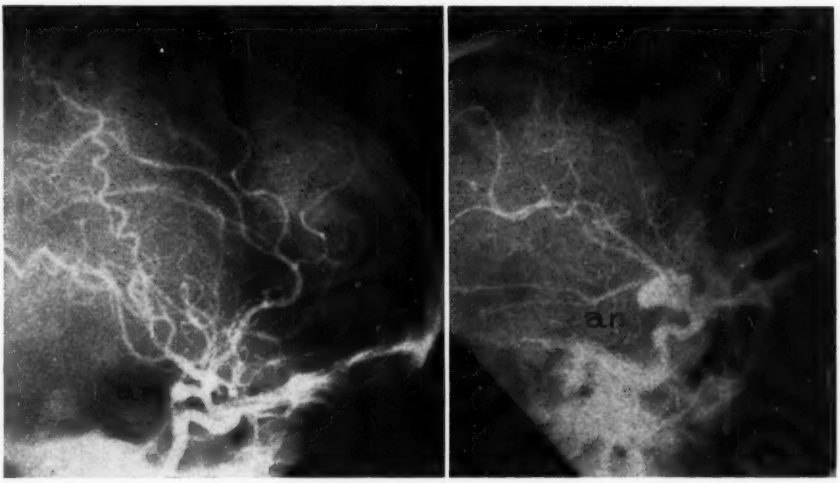


FIG. 16 (*left*). Aneurysm of internal carotid artery, intracranial portion.

FIG. 17 (*right*). Aneurysm of internal carotid artery, intracranial portion.

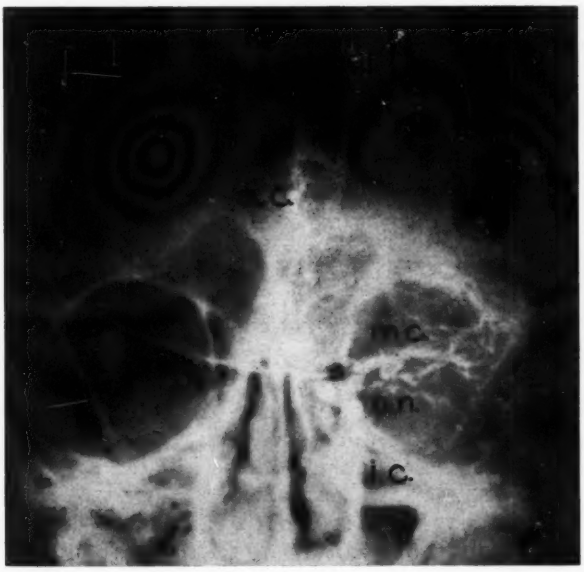


FIG. 18. Anomalous branch of intracranial portion of internal carotid artery (seen as small filament above a.n.).

the carotid between the ophthalmic and posterior communicating arteries may persist as mature vessels in the adult is shown in Fig. 18. This vessel ran laterally under the temporal lobe from the lateral aspect of the internal carotid artery, and compressed the oculomotor nerve. There were numerous arteriosclerotic yellow plaques on the carotid artery, and it seems likely that this vessel caused difficulty only when the carotid system had become sufficiently rigid to allow it to compress the nerve. Cauterization and section of

FIG. 19. Aneurysm of terminal portion of anterior cerebral artery.

this vessel, releasing the oculomotor nerve, has permitted return of function of this nerve.

Persisting embryonic remnants appear also to be the cause of the aneurysms which appear far out in the periphery, as in Fig. 19, where medial defects are not to be anticipated to be more in profusion than elsewhere.

Fig. 7b in Padget's monograph,[15] and even more to the point, Fig. 10 in Bremer's article,[3] show the anastomoses and remnants of the network which connects the two anterior cerebral arteries. The latter figure, taken from an infant 1 week old, shows a complicated plexus, with closure of some portions, and two aneurysmal pouches with little or no outlet. Bassett[2] has elaborated on the origin of aneurysms from this area sufficiently well that it need not be repeated here.

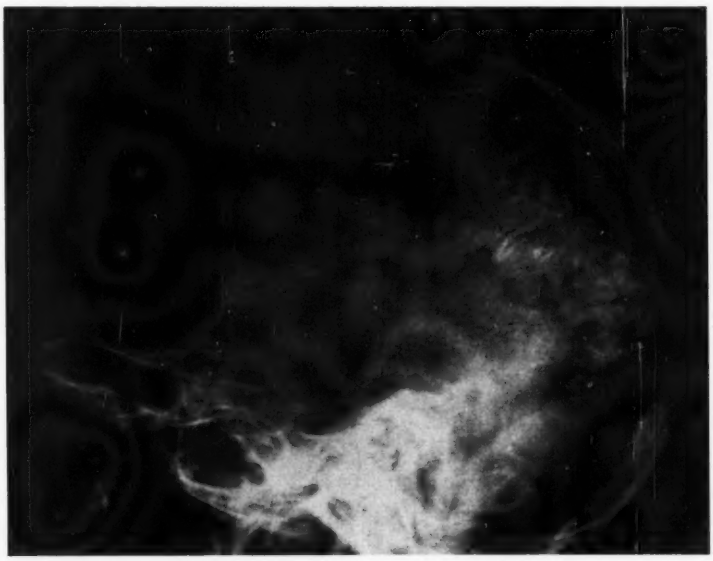

FIG. 20. Plain skull roentgenogram, showing calcification in Sturge-Weber syndrome.

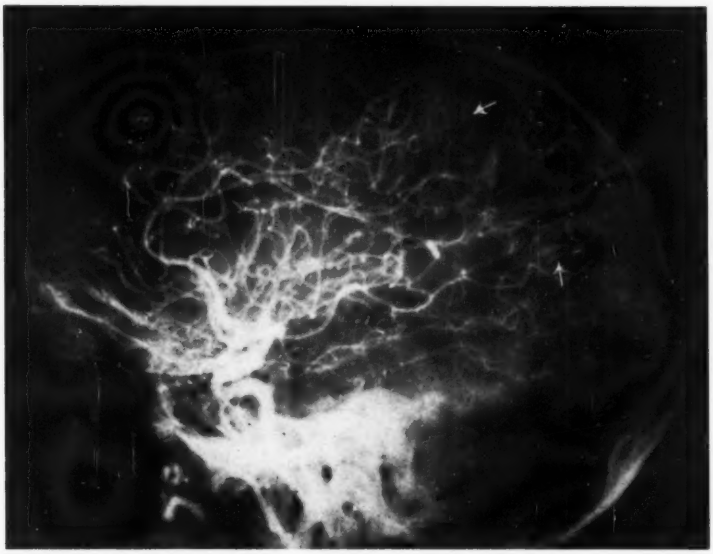

FIG. 21. Carotid angiogram, showing (arrows) abnormal vascular tufts. (Same patient as in Fig. 20.)

## TELANGIECTASES

Streeter's treatise[18] on the formation of arteries and veins from the meshwork of capillary vessels in embryonic life describes the development of the coats of the vessels. Sometimes, some of these vessels dilate without adding to their walls, forming the telangiectases which are often found in the brainstem. Most of these dilated spaces are incidental findings at autopsy, but at least one case of rupture of such spaces has been reported (Michael and Levin[14]). We have had one case in which enormous vascular spaces larger than than the aqueduct appear to have been responsible for partial

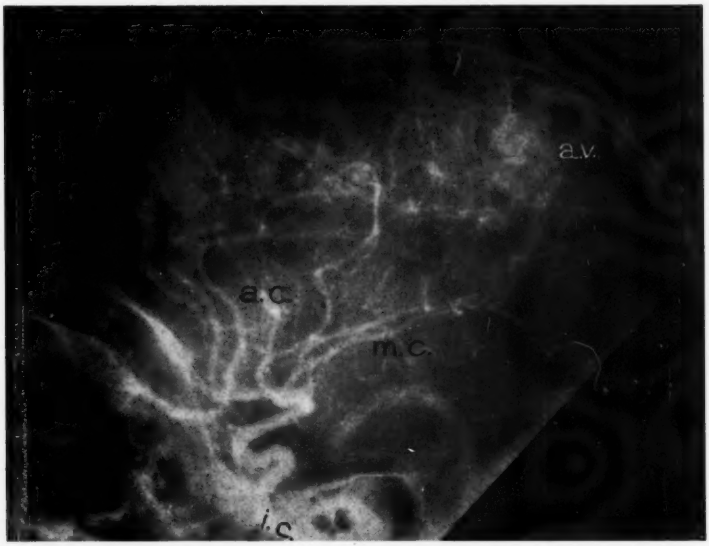


FIG. 22. Carotid angiogram in Sturge-Weber's syndrome, with vascular tangle.

occlusion of the aqueduct, leading to obstructive hydrocephalus, and one has been reported by Carpenter and Dillard.[4] Angiograms of such telangiectases have not yet been carried out. However, angiograms have been made of the vascular anomaly frequently classed as telangiectasis, and known variously as Sturge-Weber disease or trigeminal encephaloangiomatosis. The basic lesion appears to be dilated pial venous channels, causing stasis in the capillary bed, leading to ischemia and deposition of calcium (Lichtenstein and Rosenberg[12]). Fig. 20 shows a typical calcification in such a patient, and Fig. 21 shows the angiogram of this same patient. The arrows point to clusters of tiny vessels, near but outside of the area of calcification.

Sometimes a more definite vascular anomaly is associated with the facial nevus and occipitoparietal calcification, as in Fig. 22, taken of a child with seizures as a part of her syndrome.

FIG. 23 (*left*). Arteriovenous malformation (verified at operation) of Rolandic area.

FIG. 24 (*right*). Arteriovenous malformation (verified by operation) under frontal lobe.

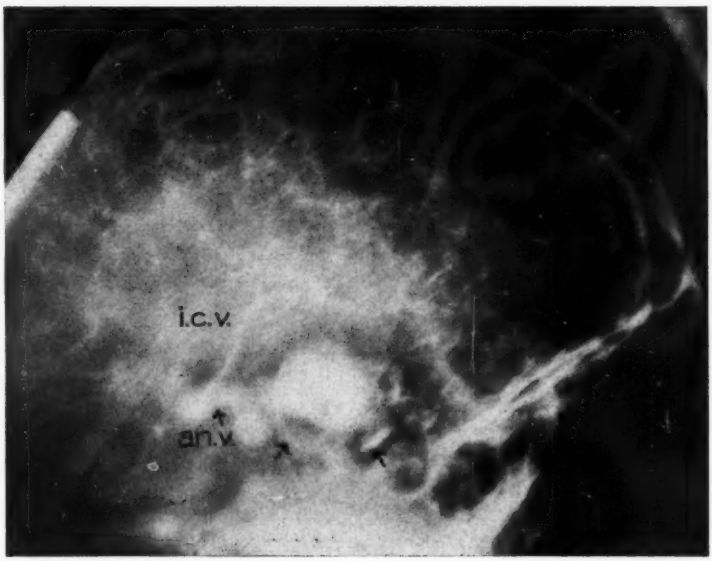


FIG. 25. Arteriovenous malformation (verified by operation) with saccular aneurysm outlined by calcium (arrows). Lateral phlebogram.

## ARTERIOVENOUS MALFORMATIONS

For reasons which are as yet unclear, the embryonic network may at times differentiate into abnormal communications between the arterial and venous circulations, with normal or pathologic brain tissue between the loops of vessels to differentiate them from the vascular tumors (Cushing

FIG. 26. Opened specimen removed at operation from patient of Fig. 25. The fresh blood clot is seen retracted from the walls of the aneurysm, on whose sides are portions of arteriovenous tangles.

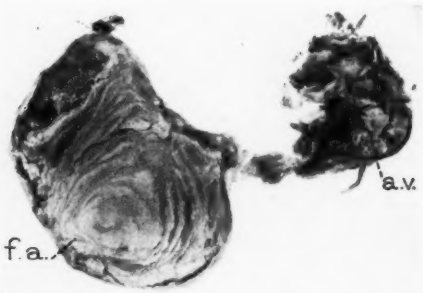


FIG. 28. Opened specimen removed at operation from patient of Fig. 27. The multilayered clot occupied about half of the sac.

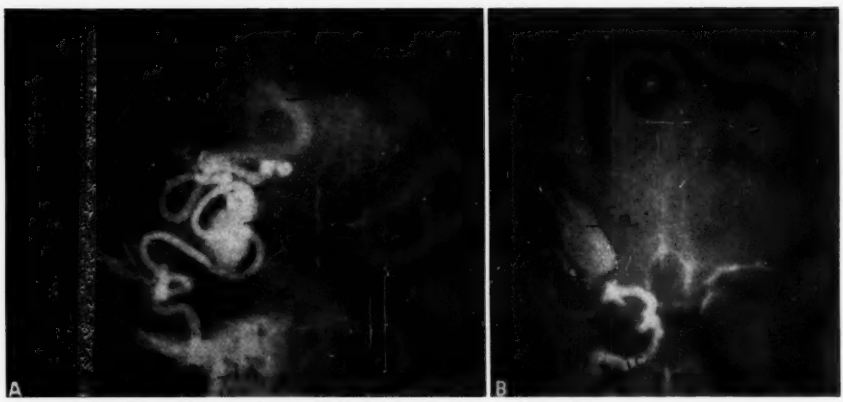


FIG. 27. Arteriovenous malformation with false aneurysm. (A) Lateral angiogram. (B) Antero-posterior angiogram. v., Hugely dilated draining vein.

and Bailey[7]). They may occur in any region of the brain, but seem to have a predilection for the Rolandic area, as in Fig. 23. The largest such tangle in our collection lay under the frontal lobe, and is shown in Fig. 24. Sometimes, what appear to be typical saccular aneurysms develop in relation to such masses (Fig. 25). A thin rim of calcium was seen in the plain roentgenograms

before angiography, and the existence of arteriovenous tangles was not suspected. Fig. 26 shows the specimen successfully removed at operation, with the sac containing fresh blood clot, and some of the abnormal vessels lying atop the sac. In another angiogram taken because of subarachnoid hemorrhage, an even larger sac was associated with the anomaly (Fig. 27). This proved, on histologic examination of the surgical specimen, to be a false aneurysm, however, with no true vascular wall (Fig. 28). There was

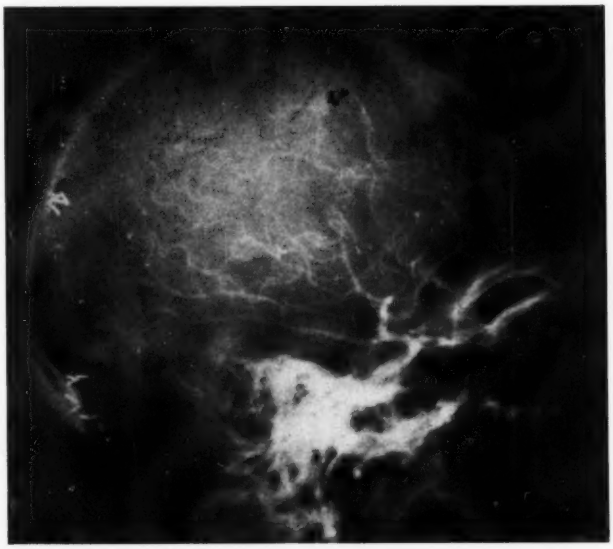

FIG. 29. Vascular anomaly in cerebrum in patient with von Hippel-Lindau's disease. Note occipital bone defect from operation for removal of cerebellar hemangioblastoma.

a clot of many layers of various ages, surrounded by a thin fibrous-tissue sheet, which was continuous with the adventitia of a large vascular channel. Doubtless, this had bled many times, and formed a protective covering which contained the clot which compressed the adjacent brain. The cavity within this sac was quite small in vivo, in contrast to the empty sac of Fig. 25, in which swirling blood was seen at the time of operation.

Although there are well-authenticated cases of purely venous channels forming a vascular anomaly, including varicose veins of the cerebrum,[5] angiograms of verified cases have not yet been reported.*

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* J. B. Curtis (Rapid serial angiography: preliminary report. *J. Neurol. Neurosurg. Psychiat.*, 1949, n.s. *12:* 167–181) has recently described and illustrated serial angiograms of a vascular malformation with only venous channels apparent.

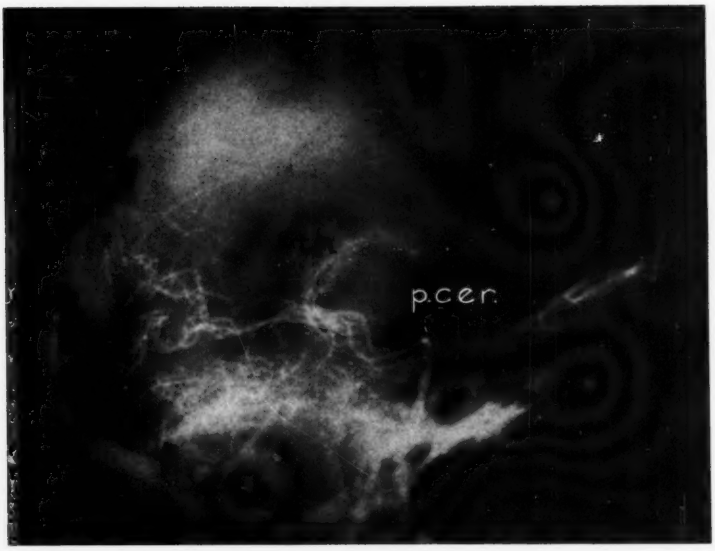


FIG. 30. Vertebral angiogram with enlarged vessels (arrows) atop a cystic hemangioblastoma of the cerebellum (verified by operation).

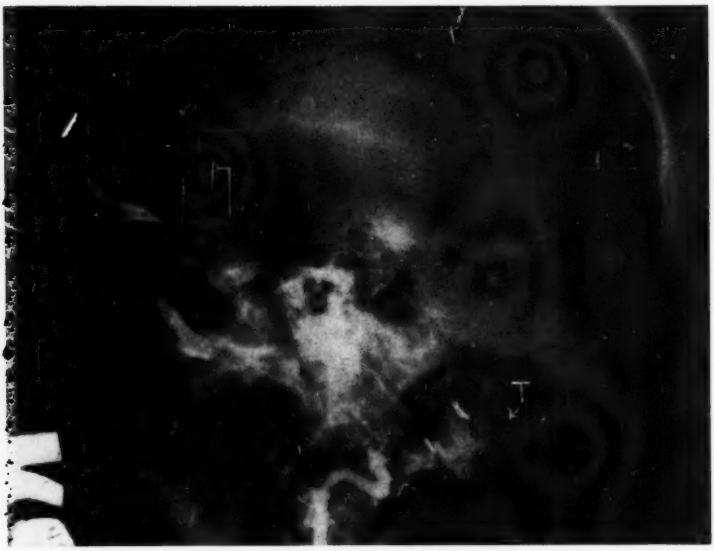


FIG. 31. Hemangioblastoma of the cerebellum. Lateral vertebral angiogram showing tumor (T.).

## HEMANGIOBLASTOMA

Although the hemangioblastomatous lesions of the brain are classified as tumors (Cushing and Bailey[7]), they appear to be predicated on an embryologic basis, and sometimes definite vascular anomalies are associated with them. The best known of these, of course, is the retinal anomaly of v. Hippel. Too few patients with hemangioblastomatosis have been subjected to angiography for this lesion to have appeared. Others have been observed, however, as in Fig. 29. This malformation in the cerebrum caused focal

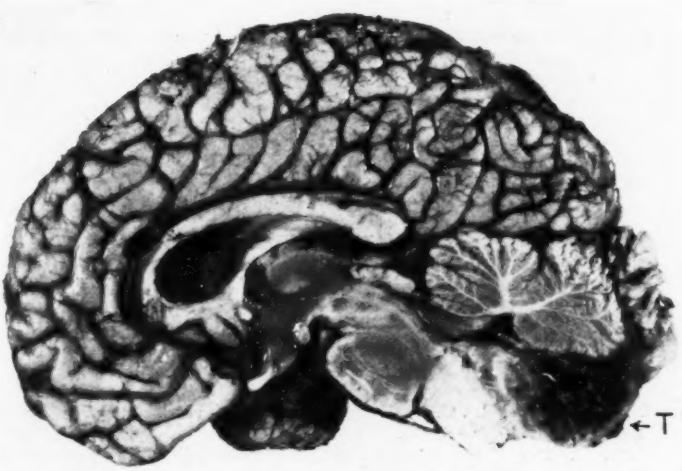


FIG. 32. Sagittal section of gross autopsy specimen from patient of Fig. 31.

seizures in a woman who had survived removal of a cerebellar hemangioblastoma some years after she became completely blind as a result of vascular anomalies of both retinae. It may well be that similar lesions have been responsible for focal seizures in other patients with cerebellar hemangioblastoma, in which parietal craniotomies have been futile in disclosing the focus of seizure activity.

The vertebral angiogram shown in Fig. 30 shows the abnormally large vessels which overlay a cystic hemangioblastoma of the cerebellum, confirmed by operation. The richness of the blood supply of these masses may also be seen in Figs. 31 and 32, showing the angiogram and pathologic specimen from a man in whom only a suboccipital decompression was done because of the enormous blood loss. Angiography was done shortly thereafter to visualize the extent of the bloody tumor, but the patient died before he could be put in sufficiently good condition to withstand another operative procedure.

## *Postscript*

Mrs. Padget writes that she may undertake the task of trying to describe and depict the development of the veins of the human embryo: doubtless such an endeavor will extend even further our understanding of the genesis of intracranial vascular anomalies (such as sinus pericranii), and thus permit a more rational surgical attack on these interesting lesions.

## REFERENCES


1. Altmann, F. Anomalies of the internal carotid artery and its branches; their embryological and comparative anatomical significance. Report of a new case of persistent stapedial artery in man. *Laryngoscope, St. Louis*, 1947, *57:* 313–339.
2. Bassett, R. C. Intracranial aneurysms. I. Some clinical observations concerning their development. *J. Neurosurg.*, 1949, *6:* 216–221.
3. Bremer, J. L. Congenital aneurysms of the cerebral arteries. An embryologic study. *Arch Path.*, 1943, *35:* 819–831.
4. Carpenter, C. C., and Dillard, P. H. Obstruction of the aqueduct of Sylvius as a cause of internal hydrocephalus and death. A report of two cases. *N. C. med. J.*, 1949, *10:* 594–598.
5. Case Records of the Massachusetts General Hospital. Case 24121. *New Engl. J. Med.*, 1938, *218:* 529–531.
6. Congdon, E. D. Transformation of the aortic-arch system during the development of the human embryo. *Contr. Embryol. Carneg. Instn.* 68, 1922, *14:* 47–110.
7. Cushing, H., and Bailey, P. Tumors arising from the blood-vessels of the brain. Angiomatous malformations and hemangioblastomas. *Springfield, Ill.: Charles C Thomas*, 1928, x, 219 pp.
8. Dandy, W. E. Intracranial arterial aneurysms. *Ithaca, N. Y.: Comstock Publishing Co., Inc.*, 1944, viii, 147 pp.
9. Forbus, W. D. On the origin of miliary aneurysms of the superficial cerebral arteries. *Johns Hopk. Hosp. Bull.*, 1930, *47:* 239–284.
10. Forster, F. M., and Alpers, B. J. Aneurysm of circle of Willis associated with congenital polycystic disease of the kidneys. *Arch. Neurol. Psychiat., Chicago*, 1943, *50:* 669–676.
11. Green, J. R., and Arana, R. Cerebral angiography. A clinical evaluation based on 107 cases. *Amer. J. Roentgenol.*, 1948, *59:* 617–650.
12. Lichtenstein, B. W., and Rosenberg, C. Sturge-Weber-Dimitri's disease. Report of an abortive case with observations on the form, chemical nature, and pathogenesis of the cerebral cortical concretions. *J. Neuropath. exp. Neurol.*, 1947, *6:* 369–382.
13. Marx, F. An arteriographic demonstration of collaterals between internal and external carotid arteries. *Acta radiol., Stockh.*, 1949, *31:* 155–160.
14. Michael, J. C., and Levin, P. M. Multiple telangiectases of the brain. A discussion of hereditary factors in their development. *Arch. Neurol. Psychiat., Chicago*, 1936, *36:* 514–529.
15. Padget, D. H. The development of the cranial arteries in the human embryo. *Contr. Embryol. Carneg. Instn.* 212, 1948, *32:* 205–261.
16. Richardson, J. C., and Hyland, H. H. Intracranial aneurysms. A clinical and pathological study of subarachnoid and intracerebral haemorrhage caused by berry aneurysms. *Medicine, Baltimore*, 1941, *20:* 1–83.
17. Schwartz, H. G. Arterial aneurysm of the posterior fossa. *J. Neurosurg.*, 1948, *5:* 312–316.
18. Streeter, G. L. The development of the venous sinuses of the dura mater in the human embryo. *Amer. J. Anat.*, 1915, *18:* 145–178.
19. Sugar, O., Holden, L. B., and Powell, C. B. Vertebral angiography. *Amer. J. Roentgenol.*, 1949, *61:* 166–182.
20. Sugar, O., and Tinsley, M. Aneurysm of terminal portion of anterior cerebral artery. *Arch. Neurol. Psychiat., Chicago*, 1948, *60:* 81–85.
21. Sunderland, S. An anomalous anastomosis between the internal carotid and basilar arteries. *Aust. N.Z. J. Surg.*, 1941, *11:* 140–142.
22. Sunderland, S. Neurovascular relations and anomalies at the base of the brain. *J. Neurol. Neurosurg. Psychiat.*, 1948, n.s. *11:* 243–257.

# DURAL SINUS VENOGRAPHY AS AN AID TO DIAGNOSIS IN INTRACRANIAL DISEASE*

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WHILE the numerous adjuncts to diagnosis of intracranial tumors and other intracranial diseases have reached a high degree of accomplishment, investigative studies of the intracranial venous system, but for a few exceptions, have been lacking. Intracranial angiography by injection of contrast media into the carotid or vertebral arteries can usually be relied on to provide adequate evaluation of the arterial system of the head but often scanty information about the venous system.

The special methods of investigation of the intracranial venous system to be reported have thus far brought to light some interesting facts and proven of practical use. They may possibly introduce a new avenue of investigation that will prove valuable not only in intracranial tumors but in other conditions that alter the intracranial veins.

The methods employed include: (a) direct injection into the superior sagittal sinus of a contrast medium through a catheter introduced into the sinus; (b) retrograde injection of a contrast medium through a catheter introduced into the basilic vein of the arm passed upward into the internal jugular vein to the superior bulb; and (c) direct measurement of the venous pressure.

## METHOD

*Superior Sagittal Venogram.* Local anesthesia is employed routinely. The head is slightly elevated to avoid possible air embolism and to minimize bleeding from the sinus. A 4 to 5 cm. longitudinal incision is made directly in the midline and centered at or slightly in front of the hairline. A burr hole is made, care being taken not to injure the underlying sinus. Additional bone is removed with the rongeurs if greater exposure seems necessary. A small incision is made in the superior wall of the sinus and a #8 ureteral catheter inserted and passed posteriorly for 3 or 4 cm. A steady stream of venous blood should be obtained when negative pressure is applied to a syringe attached to the catheter. If a good flow is not obtained, the catheter is not in the sinus and should be replaced.

Saline containing heparin (1 cc. in 500 cc. saline) is injected at intervals to prevent clotting. Cotton pledgets are packed about the catheter and the wound is temporarily closed. The spinal fluid manometer containing a heparinized saline solution is attached to the catheter to measure the venous pressure in the sinus at rest and after compression of the jugular veins.

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* Presented at the meeting of the Harvey Cushing Society, Colorado Springs, Colorado, April 16, 1950.

In the X-ray department, roentgenograms are made at $\frac{1}{2}$ second exposure in the anteroposterior and lateral positions after rapid injection of 15 cc. of Diodrast (35 per cent). For best results the injection must be made as rapidly as possible. There are no symptoms attending the injections save the characteristic flushed sensation a few seconds later.

In the operating room the wound is reopened and the cotton pledgets and catheter are removed. Bleeding from the defect in the sinus is controlled with Gelfoam sponge and the wound closed. In some patients Gelfoam is packed in the burr hole about the catheter when the wound is initially closed and following the roentgenograms the catheter is removed without reopening the wound. If the venous pressure is high, however, it is safer to reopen the wound and be sure that bleeding from the sinus is controlled.

*Retrograde Jugular Venogram.* Local anesthesia is used. A catheter of the type employed in angiocardiography is inserted in a basilic vein in the arm and under fluoroscopic control passed upward through the subclavian vein and into the internal jugular vein to the superior bulb. Twenty-five cc. of 75 per cent Diodrast are injected rapidly and lateral roentgenograms secured at $\frac{1}{2}$ second exposure. Pressure is made on both jugular veins during the injection. The patients complain of some headache during the injections and for 5 to 10 seconds afterwards. There are no other untoward symptoms.

Sometimes there is difficulty in getting the catheter to pass from the subclavian vein into the internal jugular vein and manipulation of the head and neck is required. Attempts to pass the catheter into the transverse sinuses have thus far been without success, probably due to the acute angle at which the sinus joins the superior bulb of the internal jugular vein. Venous pressure determinations may be made by attaching a manometer to the catheter.

## RESULTS

*In the normal* (Fig. 1), there are certain constancies and variations of the venous pattern outlined by injection of contrast medium into the superior longitudinal sinus by the method described. The medium rapidly passes back through the longitudinal sinus, thence into the transverse sinuses and internal jugular veins. The other dural sinuses and the cerebral veins are not visualized though sometimes venous lacunae along the margin of the sinus and short segments of a few superior cerebral and diploic veins are seen. Also, if the catheter does not occlude the lumen of the sinus, occasionally the most anterior end of the sagittal sinus and short segments of the orbital and facial veins are visualized.

Compression of the jugular veins, one or both, for 15 seconds does not usually cause the contrast medium to pass into the cerebral veins nor alter the relative degree of filling of the transverse sinuses. It does, however, result in extensive filling of the occipital and vertebral system of veins.

The relative size and filling of the transverse sinuses in our first group of 12 normal patients were evaluated (Table 1). In 3 cases the transverse sinuses filled equally well and were the same approximate size. There was complete absence of filling of the left transverse sinus in 1 case and of the right in 1 case. In the remaining cases there appears to be a predominance

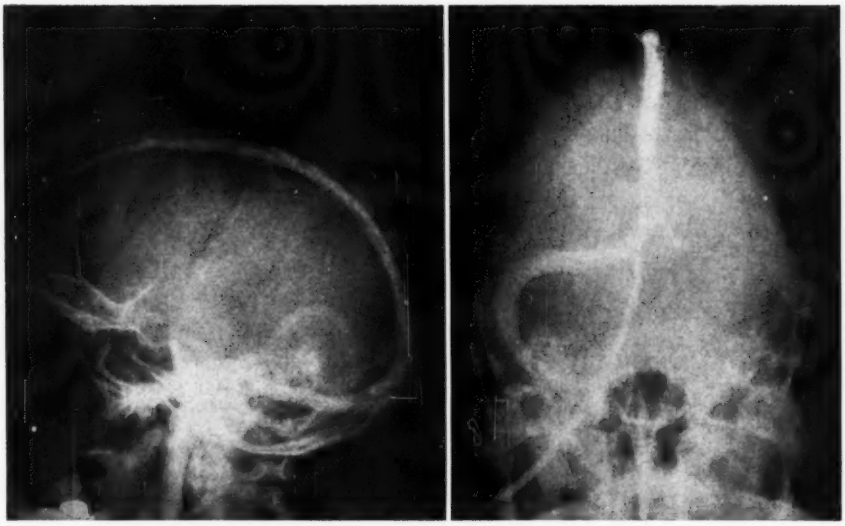

FIG. 1. Normal venograms (lateral and A.P.) after injection of Diodrast into the anterior end of the superior sagittal sinus.

in size of one or the other of the transverse sinuses in a nearly equal ratio. These findings in a small series indicate that while the superior sagittal sinus often drains more, and occasionally wholly, into one transverse sinus, there is not an impressive dominance of the right over the left. This is not in keeping with the commonly accepted statement that the right trans-

TABLE 1

*Relative filling of the transverse sinuses by injection of the superior sagittal sinus in 12 normal patients*

| | Right | Left | |
|---|---|---|---|
| 1. | Good | Poor | 4 right dominant |
| 2. | Good | Poor | |
| 3. | Good | Poor | |
| 4. | Good | 0 | |
| 5. | Poor | Good | 5 left dominant |
| 6. | Poor | Good | |
| 7. | Poor | Good | |
| 8. | Poor | Good | |
| 9. | 0 | Good | |
| 10. | Good | Good | 3 equal |
| 11. | Good | Good | |
| 12. | Good | Good | |

verse sinus predominantly receives the flow from the superior sagittal sinus. But experiences with a larger series of cases will be necessary in order to throw more light on the matter.

Retrograde jugular venogram (Fig. 2) with the catheter at the superior bulb of the internal jugular vein showed good filling with contrast medium of the superior and inferior petrosal sinuses and less often of the cavernous

FIG. 2. Normal venogram after retrograde injection of Diodrast into the superior bulb of one jugular vein.

sinus and transverse sinus of the same side. There was also good filling of the vertebral, orbital and facial veins and the pterygoid plexus. The exact extent of filling in the normal is not yet clear but it appears that there should be filling at least of the petrosal and cavernous sinus and the vertebral and pterygoid plexuses of veins.

The normal venous pressure in the superior longitudinal sinus was found to be between 120 and 150 mm. of water, a pressure comparable to that of the cerebrospinal fluid. Straining or temporary occlusion of the jugular vein caused a prompt rise in the venous pressure in the sinus and a prompt fall on release of pressure. Compression of the jugular vein on the side where the transverse sinus was known to be occluded did not elevate the level of pressure in the sagittal sinus but sometimes caused it to fall, possibly due to a carotid sinus reflex fall in general systemic blood pressure. Studies carried out in an effort to correlate the rate and degree of rise of the sagittal venous pressure on jugular compression with the relative sizes of the transverse sinuses demonstrated the more prompt and greater rise when compression of the jugular vein was made on the side of the larger sinus.

Abnormal patterns of the intracranial venous system following injection of contrast medium into the superior sagittal sinus occurred in the following cases: (a) neoplasm invading the sagittal sinus (meningiomas, Cases 1 and 2;* fibrosarcoma, Case 3) and transverse sinus (Cases 4 and 5); (b) thrombosis of the sagittal sinus (Case 6) and transverse sinus (Case 7); and (c) following ligation or resection of one transverse sinus (Cases 8 and 9).

*Case 1.* (R.G.) A 58-year-old woman gave a history of convulsive seizures and progressive weakness on the left side for 8 years. Besides a left hemiparesis involving the lower more than the upper extremity there was impairment of position sense in the left foot and a bilateral Babinski sign. Papilledema was not present and both the EEG and CSF determinations were normal. A pneumoventriculogram showed

FIG. 3. *Case 1.* Lateral and A.P. venograms by injection of Diodrast into the anterior end of the superior sagittal sinus. Due to a meningioma occluding the middle third of the superior sagittal sinus, Diodrast outlines the collateral circulation.

depression of the mid portion of the body of both lateral ventricles, greater on the right.

A sagittal sinus venogram (Fig. 3) showed obstruction of the sinus in its middle third at about the level of the Rolandic fissure. The superior cerebral and anastomotic veins in the anterior half of the head on both sides filled extensively. The anastomotic veins of Trollard and Labbé were especially prominent. The orbital and pterygoid plexuses, cavernous sinus, inferior sagittal sinus, straight sinus, petrosal sinus and internal jugular vein also filled. A small amount of contrast medium passed in the posterior one-third of the superior sagittal sinus, probably by way of collateral venous channels around the point of obstruction.

At operation a 75 gm. meningioma, which occupied both sides of the falx and

* In an additional case of centrally placed parasagittal meningioma which abutted the sinus the patency and normal configuration of the sagittal sinus were demonstrated by a sinus venogram.

completely occluded the sinus for a distance of 6 cm., was removed along with the occluded portion of the sinus. Care was taken not to damage the superior cerebral veins entering the sinus anterior and posterior to the resected portion.

For several days after operation there was weakness of all the extremities, least in the right upper, and there was also slight aphasia. There was recovery of all but the left lower extremity where the weakness was less than it had been before operation.

*Case 2.* (M.T.) A 31-year-old woman gave a history of convulsive seizures, often lateralized to the right, of 5 years' duration. There was papilledema, slight weakness

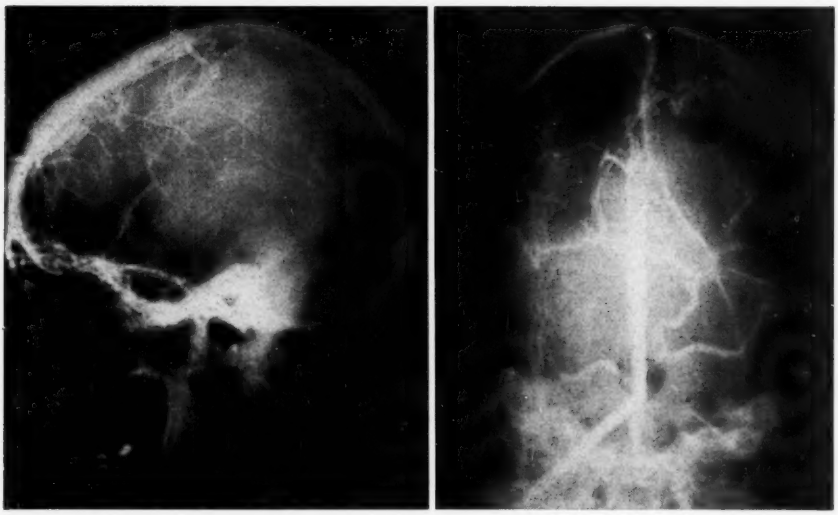

FIG. 4. *Case 2.* Lateral and A.P. venograms by injection of Diodrast into the anterior end of the superior sagittal sinus. Due to a meningioma occluding the middle third of the superior sagittal sinus, Diodrast outlines the collateral circulation.

of the right extremities and impairment of position sense in the right foot. The EEG was normal.

A sagittal sinus venogram (Fig. 4) showed obstruction of the sinus in its middle third at about the level of the Rolandic fissure. The superior cerebral and anastomotic veins in the anterior half of the head on both sides filled extensively. The anastomotic veins of Trollard and Labbé were especially prominent. The orbital and pterygoid plexuses, cavernous sinus, inferior sagittal sinus, straight sinus, petrosal sinus and internal jugular vein also filled. A small amount of contrast medium passed in the posterior one-third of the superior sagittal sinus probably by way of collateral venous channels around the point of obstruction. The patient's condition was not changed by this procedure and she was in excellent condition in the following few hours before pneumoventriculogram was performed.

The pneumoventriculogram showed distortion of the ventricular system indicative of a left-sided centrally placed parasagittal tumor. Shortly following this

procedure the patient became comatose and craniotomy was hurriedly performed. An 80 gm. meningioma, which occupied the right central parasagittal region and filled the lumen of the sagittal sinus for a distance of 4 cm., was removed along with the occluded portion of the sinus. Although this part of the operation was not difficult the brain was under considerable tension from the start and it was necessary to sacrifice the bone plate for decompression when the wound was closed. The patient did not regain consciousness and it is believed that her death on the 3rd day after craniotomy resulted from a temporary pressure cone at the tentorium or the foramen magnum which developed during the performance of the ventriculogram.

*Case 3.* (P.O.) A 50-year-old white female gave a 15-year history of a recurrent tumor on the vertex of the scalp. The tumor had been excised 30 times but always

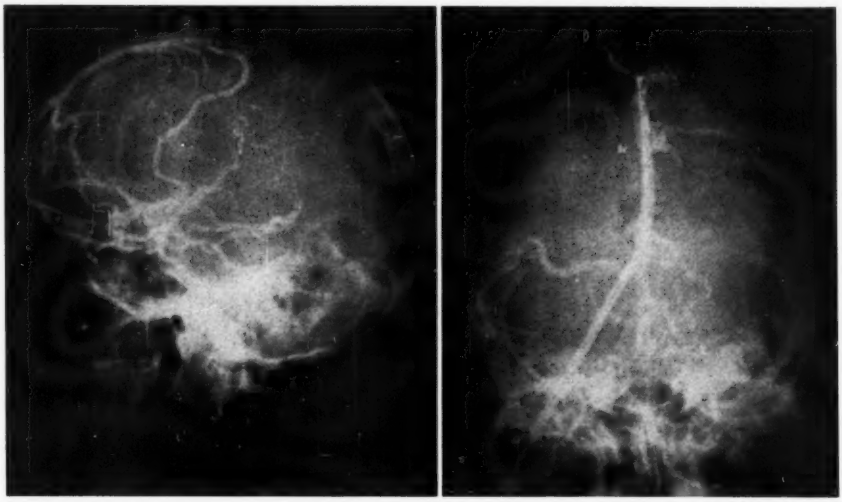

FIG. 5. *Case 3.* Lateral and A.P. venograms by injection of Diodrast into the anterior end of the superior sagittal sinus. There is erosion of the skull at the vertex due to a sarcoma which has also occluded the middle third of the superior sagittal sinus, causing the development of collateral circulation.

recurred. Also, a series of 40 X-ray treatments were given over a 5-year period. Histologically, the tumor was classified as dermatofibrosarcoma protuberans.

The patient's only complaint during her entire illness was a mild generalized headache. Examination revealed a granular tumor nodule, 2.5×2.5 cm., directly over the vertex. The surrounding scalp for about 5 cm. was hairless and atrophic. There was no papilledema. There were no palpable lymph nodes about the head and neck. Roentgenograms of the skull showed a 4 cm. defect at the vertex. There was no evidence of metastases.

A sagittal sinus venogram (Fig. 5) showed obstruction in the mid portion of the sagittal sinus without filling of the sinus posterior to the obstruction. There was good filling of the diploic, scalp and superior cerebral veins anterior to the obstruction. The inferior sagittal and straight sinuses filled well and by way of these channels some of the Diodrast entered the transverse sinuses. Venous pressure in the sagittal

sinus was 300 mm. of saline. Pressure on one or both jugular veins for 5 seconds did not change the pressure in the sinus.

A subsequent craniotomy showed that the tumor had invaded and completely occluded 6 cm. of the middle part of the superior sagittal sinus and also extended for a short distance into several of the superior cerebral veins. The involved veins were divided beyond the tumor extension and the sinus was divided anterior to the tumor. When the sinus was divided posterior to the obstruction a 5 cm. "tail" of the tumor unattached to the walls of the sinus was found to extend backward in the lumen of the sinus toward the torcular Herophili. It was readily lifted out. The segment of sinus resected measured 6½ cm. The dural and scalp defects were repaired with suitable grafts and but for slight transient weakness in both lower extremities for a few days recovery was uneventful.

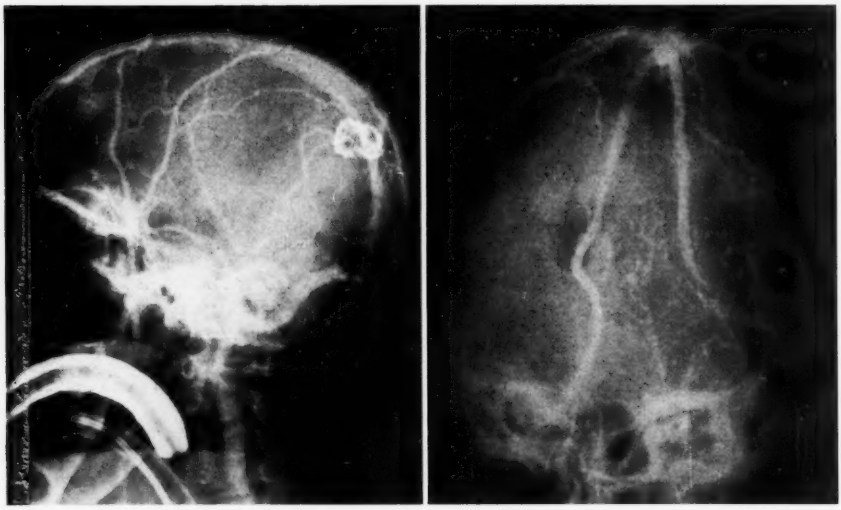

FIG. 6. *Case 4.* Lateral and A.P. venograms by injection of Diodrast into the anterior end of the superior sagittal sinus. The occipital bone has been widely resected because of a hyperostosing meningioma. Tumor invading the dura in this region has completely occluded the right and partly occluded the left transverse sinuses, causing the development of collateral circulation.

*Case 4.* (A.S.) A 63-year-old woman gave a history of headaches and blurred vision of recent origin and a gradually increasing swelling of the back of the head of 2 years' duration. Papilledema was the only abnormal neurologic sign. In a two-stage operation (in 1946) a large hyperostosing meningioma of the occipital bone growing into the posterior fossa was resected. The dura in the region of the torcular Herophili and transverse sinuses was adherent to the tumor. After operation, a sinus venogram was performed by injection of diodrast by needle introduced into the anterior portion of the superior sagittal sinus exposed through a burr hole. The pattern of the venous system did not appear abnormal on this venogram.

The patient returned 4 years later (1950) with a recurrent growth of the tumor in the occiput.

A sagittal sinus venogram (Fig. 6) by the present technique showed an irregular defect in the region of the torcular Herophili, absence of filling of the right transverse sinus and an irregular outline of the left sinus. Venous pressure in the sinus was 350 mm. of saline. There was no rise with jugular compression on the right and only a slight rise with jugular compression on the left. There was extensive filling of the superior cerebral veins, the veins of Labbé, diploic and anastomotic scalp veins. The filling of the collateral venous channels was the result of the partial obstruction by invasive growth of the tumor at the torcular Herophili. At subsequent operation the invasion of the sinus by tumor was verified.

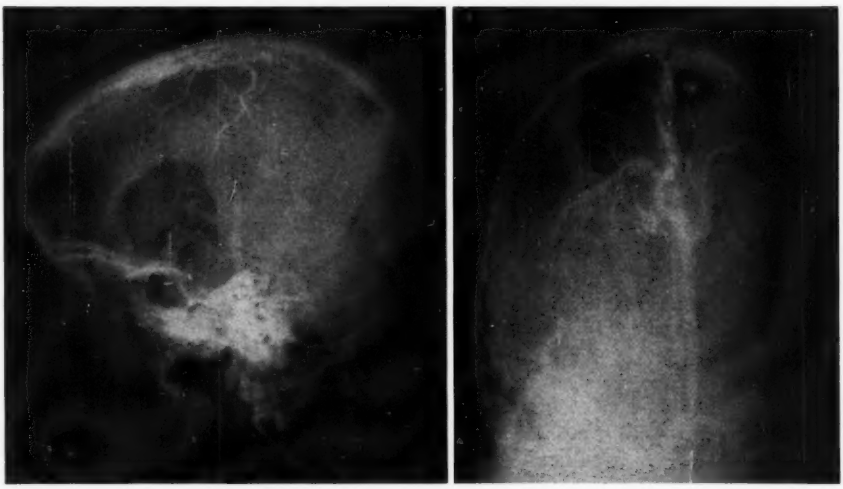

FIG. 7. *Case 6.* Lateral and A.P. venograms by injection of Diodrast into the anterior end of the superior sagittal sinus. The posterior half of the sinus is occluded by thrombosis, causing the development of collateral circulation.

*Case 5.* (W.C.) A 63-year-old male had a 5-year history of multiple epidermoid carcinomas of the head and neck. On admission he had a large ulcerating carcinoma over the left mastoid region extending into the external auditory canal, the mastoid cells and the middle ear. At operation the tumor was found to have extended into the dura of the middle fossa. In an attempt to evaluate the actual intracranial extension of the tumor a sagittal sinus venogram was performed.

The venogram showed good filling of the superior sagittal and both transverse sinuses, the left being slightly larger than the right. In the most lateral portion of the left transverse sinus there was an irregular filling defect indicating invasion of the lumen by tumor. The operation which had been performed prior to the venogram had strongly suggested this possibility.

*Case 6.* (I.C.) A 48-year-old female had a 6-month history of headache, diplopia, and gradual loss of vision. Except for bilateral papilledema the physical examination was unremarkable. The CSF pressure was 480 mm. Repeated cultures of the CSF were negative. Ventriculograms showed small ventricles without displacement. Bi-

lateral subtemporal decompressions were performed but she continued to lose vision and her signs and symptoms remained unchanged over an 8-month period.

A sagittal sinus venogram (Fig. 7) showed obstruction of the sinus at the junction of the posterior and middle one-third. There was good filling of the superior cerebral veins anterior to the point of obstruction but none of the contrast medium entered the posterior one-third of the superior sagittal sinus. The inferior sagittal sinus, straight sinus, diploic veins and anastomotic scalp veins also were filled. Venous pressure in the sagittal sinus was 480 mm. of saline.

A retrograde jugular venogram on the right side showed filling of the internal jugular vein only. None of the contrast medium passed into any of the intracranial veins or venous sinuses. Pressure in the right internal jugular vein (superior bulb) was 32 mm. of saline.

A retrograde jugular venogram on the left side showed good filling of the superior and inferior petrosal, and cavernous sinuses, orbital veins, pterygoid plexus, vertebral veins, and deep facial veins. Because of technical difficulties venous pressures were not obtained.

Several weeks later the posterior one-third of the superior sagittal sinus was exposed and a thrombus, which completely occluded the sinus, was removed with suction and forceps until a brisk flow of blood was obtained from both directions.

The patient was given anti-coagulant therapy (heparin and dicumerol) for 3 weeks postoperatively and steadily improved. Her CSF pressure fell to 200 mm. in a week and 3 months after operation was normal. Her papilledema and diplopia disappeared and she had headache only occasionally.

Six weeks after the operative removal of the clot the sagittal sinus venogram was repeated. The venous pressure in the sinus had fallen to less than 300 mm. of saline. The venograms showed a block in the same part of the sinus as before but filling of the superior cerebral veins and anastomotic veins had greatly increased. The patient was discharged from the hospital and has remained well, now about 5 months.

*Case 7.* (W.S.) A 60-year-old man had a 3-day history of right-sided earache, headache, chills and fever and increasing drowsiness. Examination showed a right facial palsy and tenderness over the right mastoid. There were 500 polymorphonuclear cells/c.mm. of CSF. The CSF pressure was not elevated. The Tobey-Ayer test indicated a block on the right side. Skull roentgenograms showed complete destruction of the mastoid cells on the right.

A superior sagittal venogram (Fig. 8) showed good filling of both transverse sinuses. There was, however, an obstruction in the sigmoid portion of the right transverse sinus and none of the contrast medium passed beyond this point. Venous pressure in the sagittal sinus was 200 mm. of saline. A radical mastoidectomy was performed the following day and a large amount of necrotic bone and pus was removed. The sigmoid portion of the transverse sinus was exposed and a large thrombus was found in the position indicated by the sagittal venogram.

*Case 8.* (M.F.) A 50-year-old woman had a recurrence of a meningioma of the left side of the tentorium cerebelli. Over a period of the previous 17 years she had 4 operations for removal of the tumor. On one of these occasions the entire left transverse sinus was excised; it was of relatively large calibre. At the time of her last admission it was thought advisable to perform a sinus venogram in order to determine any

alteration of the intracranial venous pattern that may have resulted from the previous excision of the left transverse sinus.

A sagittal sinus venogram showed good filling of the superior sagittal and right transverse sinuses only. There was no filling of any collateral veins, indicating that the intracranial venous drainage had not been compromised by the loss of one transverse sinus.

*Case 9.* (T.P.) A 45-year-old female had a 5-year history of headache and a slowly growing mass behind the left ear. A meningioma arising from the left side of

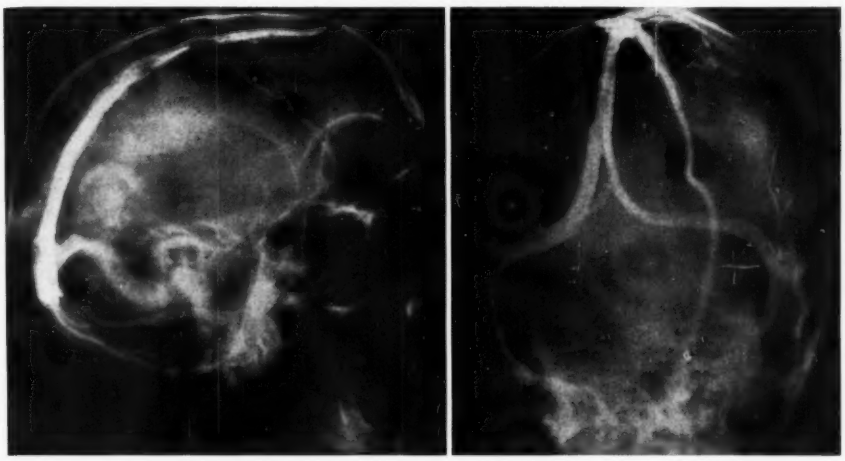

FIG. 8. *Case 7.* Lateral and A.P. venograms by injection of the anterior end of the superior sagittal sinus. There is occlusion of the right transverse sinus (in the sigmoid portion) by thrombosis.

the tentorium was removed. The excision included a large segment of the left transverse sinus which was invaded by the tumor.

A superior sagittal venogram was done 3 months later and showed good filling of the right transverse sinus and complete absence of filling of the left transverse sinus. Venous pressure in the sagittal sinus was 180 mm. of saline.

## DISCUSSION

In the past there has been sporadic interest in the anatomy and dynamics of the intracranial venous system. The anatomists for many years have drawn attention to the variations in the direction of venous outflow from the brain but none of the theories proposed for the explanation of these variations satisfactorily accounts for all of them. The Queckenstedt test,[12] first introduced in 1916, is based on the engorgement of the intracranial veins by temporary occlusion of the internal jugular veins and the reflected rise in cerebrospinal fluid pressure. The Tobey-Ayer modification[15] of the test in 1925 was designed particularly for the detection of thrombosis of the

transverse sinus accompanying mastoiditis, a condition now infrequent since the advent of anti-bacterial therapy. This test depends on the fact that the transverse sinus is the chief intracranial tributary to the internal jugular vein and if the sinus is occluded compression of the jugular vein on that side does not increase the obstruction to the circulation or alter the spinal fluid pressure.

The relation of anatomic variations of the cranial venous sinuses to the effect of jugular compression in alterations of spinal fluid pressure was studied in 50 cases by Edwards[6] in 1931. He concluded that the anatomic variations in the relative size of the two transverse sinuses could be expected to account for a low rise of spinal fluid pressure on compression of one jugular vein in many normal persons and that a normal response has far more significance in excluding pathologic obstruction than has a poor response in indicating such an obstruction.

In a review of the important literature on the subject Woodhall[16] in 1939 discussed the anatomy of the cranial blood sinuses with particular reference to the transverse sinuses. He was to able show that the presence and the size of the transverse sinuses could often be determined reliably by plain roentgenograms of the skull and he emphasized the clinical importance of this information when dealing with thrombosis or neoplasms occluding the sinuses.

Dandy[4] in 1940 collected the reports of 9 cases from the literature and added 4 of his own in which portions of the superior sagittal sinus were resected in the course of tumor extirpations. He was interested particularly in whether resection of the sinus would be tolerated and was forced to conclude that while segments of the sagittal sinus which had been gradually occluded by tumor could be successfully removed there was no evidence to support or deny that a patent sinus could be similarly resected with safety. This continues to be an important but unresolved problem and has been discussed anew by Browder and Kaplan.[3]

A necessary and timely study of the dynamic circulatory patterns of the brain through quantitative determinations of cerebral blood flow in man was made by Shenkin, Harmel and Kety.[14] They were able to show among other things that blood entering the brain via the internal carotid artery is under normal conditions distributed almost wholly to the ipsilateral hemispheres and drained predominantly by the internal jugular vein on the same side although the external jugular vein drains a significant fraction (22 per cent) of the cerebral venous blood.

The importance of an understanding of the anatomy and dynamics of the intracranial venous system is further affirmed by the evident interest of investigators in relatively unrelated problems. Batson,[1] in an admirable study of the function of the vertebral veins, was able to show that through this system of veins there is a direct and rich anastomosis between the intracranial veins and the venous divisions of the body. Through the connections of the vertebral venous system it is possible to explain many of the pyogenic

and neoplastic metastases that heretofore were considered paradoxical. Gius and Grier[9] have recently reintroduced the problems of adaptation of the veins of the brain and head following resection of the jugular veins in the course of radical operations for neoplasms of the head and neck. Beck,[2] in introducing a new operation for improving the blood supply to the brain by the formation of an arteriovenous fistula between the carotid artery and internal jugular vein has posed many new problems pertaining to the anatomy and dynamics of blood flow in the brain.

While the utilization of the injection of opaque media into the intracranial venous system can hardly be expected to settle all the unanswered questions it does give promise of providing much needed help in a variety of circumstances. Only five past accounts of the injection of opaque media into the dural venous sinuses of living man have been found in the literature. Dixon[5] in 1934 injected an iodide preparation into a lingual vein of experimental animals and demonstrated filling of some of the intracranial veins by roentgenogram. In one patient he injected "Neo-skiodan" into the sigmoid sinus exposed by mastoidectomy and believed he demonstrated obstruction in this sinus. Frenckner[8] in 1936 reported the injection of Perabrodil through a needle passed through a small drill hole in the cranium into the sagittal sinus just above the torcular Herophili. In one case he was able by roentgenogram to show the occlusion of a transverse sinus by a thrombus; in another he was misled in diagnosing a thrombosis when a transverse sinus of small calibre failed to visualize; in a third case he was unable to make the injection presumably because of a thrombus in the sagittal sinus. Ellis[7] in 1936 reported the injection of 5 cc. of Perabrodil into the sagittal sinus at the anterior fontanelle of a 5-month-old infant with thrombophlebitis. The roentgenograms taken 5 minutes later show the dye still near the site of injection, suggesting that the material may have gotten outside the sinus. Sicard is said by Orley[11] to have injected the sagittal sinus in one patient with lipiodol but added that the injection of any oily substance into the blood stream is of questionable safety. Scott[13] in 1949 reported the injection of Diodrast by needle into the superior sagittal sinus at the anterior fontanelle in a 7-month-old child with amyotonia congenita and demonstrated an apparent block of the sinus.

Several years ago one of us (B.S.R.) employed the injection of Diodrast into the superior sagittal sinus exposed through an anterior burr hole in 3 patients presumed to have meningiomas encroaching on the sinus. Although a fairly good outline of the sagittal sinus was obtained in 2 of the patients the results were disappointing and the method was unsatisfactory. The ease and safety with which the introduction of catheters into the blood vessels and heart for angiocardiographic study has come to be used led to these new techniques for the study of the intracranial venous system. Nothing has occurred thus far to indicate that any special risk attends the procedures. The catheter in the lumen of the sinus insures against accidental injection of Diodrast outside the sinus, which is a risk if a needle is employed

for the injection, and in all respects the ease of the procedure is facilitated by the use of a catheter. The catheter has on several occasions been passed backward the full length of the sagittal sinus without any untoward effects.

The insertion of the catheter into the internal jugular vein by threading it up from a remote vein in the cubital fossa may be needlessly roundabout but the method has been demonstrated to be feasible and possesses less risk of damaging the jugular vein than a more direct injection.

More observations are needed of patients with and without intracranial disease before the normal variations in the filling of the venous system can be established and the diagnostic value of the abnormal patterns evaluated. In the normal it appears that injection of the superior sagittal sinus or the internal jugular vein can be expected to outline the major venous sinuses but cannot be expected to outline the cerebral veins, the deep venous system, veins of Galen, inferior sagittal or straight sinuses. These veins can sometimes be visualized in the "venous phase" after injection of the carotid artery (Moniz[10]) but by this method the venous shadows are often poorly defined and one obtains less information of the dynamics of venous blood flow. The two methods of visualization of the intracranial venous system can undoubtedly be used to supplement each other. For example, in a patient with a congenital arteriovenous anomaly of the cerebrum the venous components filled well after injection of the carotid with Diodrast, whereas the material moved rapidly through the dural sinuses without filling any cerebral veins when injected into the sagittal sinus. On the other hand, in a patient with obstruction of the mid portion of the superior sagittal sinus by a meningioma and in whom the anastomotic venous system had become well developed, the obstruction of the sinus and the redirection of the venous drainage of the brain were not discernible by carotid injection but adequately outlined by injection of the sinus. In the first patient the flow of blood was increased toward the sagittal sinus while in the second the flow was increased away from the sinus through its tributary veins.

The assumption that the superior sagittal sinus drains predominantly or wholly through the right transverse sinus and internal jugular vein needs to be clarified. Beck and his associates[2] have assumed that a right-sided dominance exists, that the right jugular vein drains the cerebral cortex while the left jugular vein drains deeper structures and the cerebellum. Based on this assumption he employs anastomosis of the right internal carotid artery and right internal jugular vein in order to improve the blood flow to the brain. Our studies thus far do not a show reliable dominance of the right side, indeed the flow from the sagittal sinus may sometimes be entirely into the left transverse sinus and jugular vein. Assuming that it is important for the success of the Beck operation to have the fistula on the side that connects with the superior sagittal sinus, it would seem useful then to establish first the possible dominance of one side by sinus venography.

The most important practical uses to which the methods here described can be put would at present appear to be the demonstration of partial or

complete obstruction of the superior sagittal or transverse sinuses. In the case of neoplasms obstructing a sinus this knowledge beforehand simplifies decision of the extent to which the operation for removal of the tumor should and can safely be carried. In the case of thrombosis a means is provided for more accurrate diagnosis and for evaluation of the adequacy of the anastomotic veins. But it may reasonably be anticipated that other advantages will be evident when the methods have been used in a larger number and variety of cases.

## SUMMARY

Two methods of visualization of the intracranial venous system have been developed: (a) injection of Diodrast through a catheter introduced into the anterior third of the superior sagittal sinus; (b) retrograde injection of Diodrast into the superior bulb of the internal jugular vein through a catheter passed upward from the cubital vein.

The variations in the patterns of the venous system have been studied in normal patients and in those with intracranial disease.

## REFERENCES

1. Batson, O. V. The function of the vertebral veins and their rôle in the spread of metastases. *Ann. Surg.*, 1940, *112:* 138–149.
2. Beck, C. S., McKhann, C. F., and Belnap, W. D. Revascularization of the brain through establishment of a cervical arteriovenous fistula. Effects in children with mental retardation and convulsive disorders. *J. Pediat.*, 1949, *35:* 317–329.
3. Browder, J., and Kaplan, H. Venous shunts in bilateral parasagittal meningioma. *Ann. Surg.*, 1950, *132:* 416–426.
4. Dandy, W. E. Removal of longitudinal sinus involved in tumors. *Arch. Surg., Chicago*, 1940, *41:* 244–256.
5. Dixon, O. J. Research studies in visualization of the vascular supply of the head and neck. *Trans. Amer. Acad. Ophthal.*, 1934, *39:* 351–363.
6. Edwards, E. A. Anatomic variations of the cranial venous sinuses. Their relation to the effect of jugular compression in lumbar manometric tests. *Arch. Neurol. Psychiat., Chicago*, 1931, *26:* 801–814.
7. Ellis, R. W. B. Internal hydrocephalus following cerebral thrombosis, in an infant. *Proc. roy. Soc. Med.*, 1937, *30:* 768–772.
8. Frenckner, P. Sinography: a method of radiography in the diagnosis of sinus thrombosis. *Proc. roy. Soc. Med.*, 1937, *30:* 413–421.
9. Gius, J. A., and Grier, D. H. Venous adaptation following bilateral radical neck dissection with excision of the jugular veins. *Surgery*, 1950, *28:* 305–319.
10. Moniz, E. Die cerebrale Arteriographie und Phlebographie. *Berlin: J. Springer*, 1940, viii, 413 pp.
11. Orley, A. Neuroradiology. *Springfield, Ill.: Charles C Thomas*, 1949, xii, 421 pp. (see p. 120).
12. Queckenstedt. Zur Diagnose der Rückenmarkskompression. *Dtsch. Z. Nervenheilk.*, 1916, *55:* 325–333.
13. Scott, M. A case of amyotonia congenita associated with occlusion of the sagittal sinus and bilateral subdural hygroma. Demonstration of occlusion by diotrast sinography. *J. Pediat.*, 1949, *34:* 181–194.
14. Shenkin, H. A., Harmel, M. H., and Kety, S. S. Dynamic anatomy of the cerebral circulation. *Arch. Neurol. Psychiat., Chicago*, 1948, *60:* 240–252.
15. Tobey, G. L., Jr., and Ayer, J. B. Dynamic studies on the cerebrospinal fluid in the differential diagnosis of lateral sinus thrombosis. *Arch. Otolaryng., Chicago*, 1925, *2:* 50–57.
16. Woodhall, B. Anatomy of the cranial blood sinuses with particular reference to the lateral. *Laryngoscope*, 1939, *49:* 966–1009.

# THE HEMODYNAMIC EFFECT OF UNILATERAL CAROTID LIGATION ON THE CEREBRAL CIRCULATION OF MAN*

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THE increasing incidence of surgical attack upon vascular anomalies of the brain has renewed interest in the physiological responses of the cerebral circulation to occlusion of a carotid vessel. This question has been studied in lower animals by Rein,[5] the Schneiders,[6] Bouckaert and Heymans[1] and by the late Cobb Pilcher.[4] However, because of the lack of an adequate technique for measuring the cerebral blood flow and because of the fact that lower animals have a rich intercommunication between the intracerebral and extracerebral circulations, very few data pertinent to human physiology have been accumulated.

There are two important points to be established concerning carotid ligation: firstly, its therapeutic effect, that is the degree of fall of pressure in the vessels distal to the ligation, and secondly, its safety, determined by its effect on the cerebral blood flow. Sweet and Bennett,[8] by careful measurement of pressure changes distal to ligation, have provided information on the former point. It is the latter problem that is the subject of this paper.

## METHODS

The subjects of this study were 4 patients with intracranial arterial aneurysms subjected to unilateral common carotid artery ligation. They ranged in age from 15 to 53 years (Table 1). The cerebral blood flow (CBF) was determined by means of the nitrous oxide technique[2] utilizing simultaneous observations on blood from both internal jugular bulbs in each case just before and within 10 minutes after ligation of one common carotid artery in 3 of 4 patients. In 1 case (G. W.) the control study was done immediately preceding the carotid ligation, but subsequent observations were delayed until 4 days after carotid ligation, during which time no change in the clinical state of the patient was noted.

The CBF was determined on the basis of blood from both internal jugulars because it had been previously found that two-thirds of the blood carried to the brain by one internal carotid artery was drained from the

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brain by the homolateral internal jugular vein.[7] It was thought that perhaps changes in CBF might be detected after ligation, depending upon which internal jugular drainage was analyzed.

The carbon dioxide and oxygen contents of the arterial and both jugular bloods were measured by the manometric technique of Van Slyke and Neill.[3] Mean arterial blood pressure (MABP) was obtained directly from the femoral artery by means of a damped mercury manometer. Cerebral oxygen consumption ($CMR_{O_2}$) was calculated from the formula $CMR_{O_2} = CBF \times [(A-V)_{O_2}/100]$ and the cerebrovascular resistance (CVR) was calculated from the formula $CVR = MABP/CBF$.

## RESULTS

There were no neurologic consequences of the carotid ligation in 3 of the 4 patients. In 1 patient (L. J.), the oldest in the series, within 8 minutes of ligation of the left common carotid artery, a right hemiplegia developed with loss of consciousness. The cerebral circulatory studies were started

TABLE 1

*Effects of unilateral common carotid ligation on blood gas constituents*

| | | Blood $CO_2$ Content (Vol. %) | | | | | | Blood $O_2$ Content (Vol. %) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Arterial | | Int. Jugular | | | | Arterial | | Int. Jugular | | | |
| | | C | E | C | | E | | C | E | C | | E | |
| Pt. | Age | | | O | L | O | L | | | O | L | O | L |
| S.P. | 15 | 47.0 | 48.5 | 53.2 | 52.8 | 54.8 | 54.2 | 17.3 | 17.7 | 11.2 | 11.5 | 11.7 | 11.5 |
| | | | | 53.0 | | 54.5 | | | | 11.4 | | 11.6 | |
| G.W. | 18 | 45.6 | 47.4 | 51.2 | 52.5 | 55.3 | 55.0 | 18.5 | 17.2 | 12.4 | 10.9 | 9.8 | 9.4 |
| | | | | 51.9 | | 55.2 | | | | 11.7 | | 9.6 | |
| L.J. | 53 | 51.5 | 51.4 | 58.2 | 58.0 | 57.8 | 58.0 | 12.8 | 12.3 | 5.8 | 6.1 | 5.6 | 5.5 |
| | | | | 58.1 | | 57.9 | | | | 6.0 | | 5.6 | |
| J.W. | 25 | 43.2 | 43.4 | 49.0 | 45.9 | 50.6 | 47.9 | 16.8 | 16.5 | 9.7 | 12.9 | 8.6 | 11.3 |
| | | | | 47.5 | | 49.3 | | | | 11.3 | | 10.0 | |
| Mean | 28 | 46.8 | 47.7 | 52.9 | 52.3 | 54.6 | 53.8 | 16.3 | 15.9 | 9.8 | 10.4 | 8.9 | 9.4 |
| | | | | 52.6 | | 54.2 | | | | 10.1 | | 9.2 | |

C = Control observations.
D = Observations following carotid ligation.
O = Internal jugular on side of patent carotid.
L = Internal jugular on side of ligated carotid.

TABLE 2

*Effects of unilateral common carotid ligation on cerebral circulatory functions*

| Pt. | Cerebral Blood Flow (CBF) (cc./100 g./min.) | | Cerebral Metabolic Rate ($CMR_{O2}$) (cc./100 g./min.) | | Cerebral Vascular Resistance (CVR) $\left(\frac{\text{mm. Hg.}}{\text{cc./100 g./min.}}\right)$ | | Mean Arterial B.P. (MABP) (mm. Hg.) | | Mean Pressure in Occluded Internal Carotid (mm. Hg.) | | Arteriovenous Oxygen Difference ($A-VO_2$) (Vol. %) | | R.Q. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | E | C | E | C | E | | | | | C | E | C | E |
| | O L | O L | O L | O L | O L | O L | C | E | C | E | O L | O L | O L | O L |
| S.P. | 41 63 / 52 | 53 56 / 55 | 2.5 3.7 / 3.1 | 3.2 3.5 / 3.3 | 1.8 1.2 / 1.5 | 1.8 1.7 / 1.8 | 74 | 95 | 74 | 61 | 6.1 5.8 / 6.0 | 6.0 6.2 / 6.1 | 1.01 1.00 / 1.01 | 1.05 .92 / .99 |
| G.W. | 56 46 / 51 | 52 46 / 49 | 3.4 3.5 / 3.5 | 3.9 3.6 / 3.7 | 1.5 1.8 / 1.6 | 1.9 2.2 / 2.0 | 82 | 99 | 82 | 58 | 6.1 7.6 / 6.9 | 7.4 7.9 / 7.7 | .94 .92 / .93 | 1.07 .98 / 1.03 |
| L.J. | 46 46 / 46 | 39 33 / 36 | 3.2 3.1 / 3.2 | 2.6 2.2 / 2.4 | 2.1 2.1 / 2.1 | 2.8 3.3 / 3.1 | 98 | 110 | 98 | 49 | 7.0 6.8 / 6.9 | 6.7 6.8 / 6.8 | .96 .96 / .96 | .97 .97 / .97 |
| J.W. | 70 60 / 65 | 49 49 / 49 | 5.0 2.3 / 3.7 | 3.9 2.6 / 3.3 | 1.1 1.3 / 1.2 | 1.8 1.8 / 1.8 | 77 | 87 | 77 | 62 | 7.1 3.9 / 5.5 | 7.9 5.2 / 6.6 | .82 .70 / .76 | .91 .87 / .89 |
| Mean | 53 54 / 54 | 48 46 / 47 | 3.5 3.2 / 3.4 | 3.4 3.0 / 3.2 | 1.6 1.6 / 1.6 | 2.1 2.3 / 2.2* | 83 | 98* | 83 | 58* | 6.6 6.0 / 6.3 | 7.0 6.5 / 6.8 | .93 .90 / .92 | 1.00 .94 / .97 |

C = Control observations.
E = Observations following carotid ligation.
O = Observations based on contents of internal jugular on side of patent carotid artery.
L = Observations based on contents of internal jugular on side of ligated carotid artery.
* = Significant variation.

prior to the onset of the neurologic changes and the required 10-minute period for their completion included about 6 minutes during which the patient was hemiplegic and semicomatose. Following the study, the ligature on the carotid vessel was removed and, fortunately, the patient made a complete recovery.

The data are summarized in Tables 1 and 2. Table 1 reveals that no significant changes occurred in the blood gas contents following unilateral carotid ligation.

In the 4 cases studied significant alterations following ligation occurred in the CVR (increased on the average by 47 per cent) and the MABP (increased on the average by 20 per cent). Of course a distinct fall in pressure (28 per cent) occurred in the internal carotid artery which was occluded proximally. It is interesting to note that no clear changes beyond normal limits occurred in the CBF or $CMR_{O_2}$ of the 3 patients who showed no clinical effects from the ligation. However, in the patient in whom a hemiplegia and semicoma developed following left common carotid ligation, there was a fall in CBF to abnormal levels which was occasioned by an increase of the CVR to a very high level. This patient likewise was the only one to show any real reduction of cerebral oxygen consumption after ligation, correlating well with the disturbance of consciousness which occurred.

Comparing the values in each individual of the cerebral circulatory functions (CBF, CMR, CVR, $(A-V)_{O_2}$) calculated on the basis of the blood contents from either jugular bulb, no crucial differences between the two sides as a result of the unilateral carotid artery ligation were found. Nevertheless, following ligation there did seem to be better agreement in these values, though these changes toward better agreement were not statistically significant.

## DISCUSSION

The increase in systemic MABP which followed ligation can perhaps be explained by the stimulating effect of the drop in internal carotid pressure on the carotid sinus. Unfortunately, we have never critically measured the effects on the systemic arterial pressure of ligation of the internal carotid artery distal to the carotid sinus. That this increase in systemic MABP observed here is not immediately transitory, is demonstrated by the increase in MABP noted in the 2nd patient (G.W.) whose post-ligation observations were not repeated until 4 days after operation.

The constant increase in CVR following unilateral carotid ligation was to be expected, since essentially what we were doing was eliminating a resistance in parallel. Fig. 1 illustrates this and further shows the basis upon which hemodynamic analysis can be applied to this problem in an effort to determine the changes in resistances and flows in the various cerebral vascular pathways and especially the circle of Willis after ligation of one common carotid artery.

We may assume that before ligation the shunt action of the circle of Willis is minimal and that the blood flow is equally divided between the two cerebral hemispheres. Therefore

$$I_L' = I_R' = \tfrac{1}{2}A$$

where $I_L'$ represents the blood flow through the left cerebral hemisphere before ligation and $I_R'$ represents the blood flow through the right cerebral hemisphere before ligation and A represents the total cerebral blood before carotid ligation. Also we may assume that the resistances of the two halves of the brain are equal before ligation and if this is so, since they are in

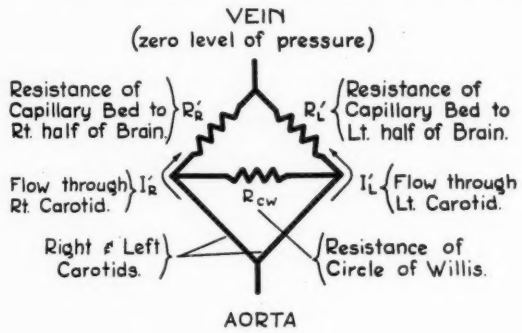


FIG. 1

parallel, the reciprocal of the total CVR is equal to the sum of reciprocals of the resistances in parallel or—

$$R_R' = R_L' = 2C$$

where $R_R'$ and $R_L'$ are the resistance of the right and left cerebral hemispheres respectively before ligation and C represents the total CVR before ligation.

The right carotid vessel is now ligated and the situation is diagramed in Fig. 2. Measurements B (total CBF after ligation), F (mean unoccluded carotid pressure), and G (mean pressure in occluded carotid) are taken. In general there are five unknowns (the resistance in each cerebral hemisphere after ligation ($R_R$ and $R_L$), the blood flow through the left cerebral hemisphere ($I_L$), the blood flow through the circle of Willis and right cerebral hemisphere ($I_R$), and the resistance across the circle of Willis ($R_{CW}$). There are only the four equations available:

$$B = I_L + I_R$$
$$F = I_L R_L$$
$$G = I_R R_R$$
$$F - G = I_R R_{CW}$$

which are insufficient for an absolute determination of the unknowns.

In the analysis of these data we can make either of two limiting assumptions. The first assumption is that the cerebral vessels are rigid and following ligation their resistance is unaltered from their preligation state $\therefore R_L = R_R = R_L' = R_R' = 2C$. The second is that the blood vessels of the brain completely adjust to the ligation and therefore the partition of blood flow

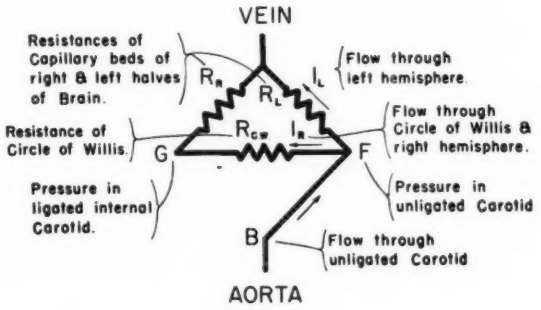


FIG. 2

through each cerebral hemisphere is maintained at its preligation level $\therefore I_L = I_R = B/2$.

With either assumption an unknown quantity is eliminated permitting a solution of the remaining unknowns with the equations available. It is probable that the actual adjustment of the cerebral circulation lies between the two extreme situations we have assumed above. Nevertheless, utilizing these assumptions we can ascertain at least the limits within which the resistance across the circle of Willis may vary. Table 3 gives results for the flow through each cerebral hemisphere and the resistance across the circle of Willis if we make the first assumption ($R_R = R_L$). Table 4 gives the calculated resistances of the two hemispheres and across the circle of Willis utilizing the second assumption ($I_L = I_R$).

TABLE 3

*Calculated values assuming that the resistance of the vasculature of each cerebral hemisphere is unaltered by carotid ligation*

| | $I_L$ | $I_R$ | Total C.B.F. | | Rc.w. | Total C.V.R. | | Rcw / $R_L$ × 100 |
|---|---|---|---|---|---|---|---|---|
| | | | Theoretical | Exp. | | Theoretical | Exp. | |
| S.P. | 34 | 22 | 56 | 54 | 1.5 | 1.7 | 1.8 | 54% |
| G.W. | 33 | 21 | 54 | 49 | 1.6 | 1.7 | 1.9 | 57% |
| L.J. | 26 | 12 | 38 | 36 | 5.1 | 2.9 | 3.1 | 120% |
| J.W. | 36 | 26 | 62 | 49 | .96 | 1.4 | 1.8 | 39% |

We note that no matter which extreme situation is assumed, in all cases the resistance of the circle of Willis is significant. In the 3 normal cases it is approximately half the resistance of each half brain before ligation. In the patient who became hemiplegic the resistance of the circle of Willis is markedly higher.

It further becomes clear that the two principal objectives of carotid ligation are to a great degree opposed, each to the other and both are related to the resistance across the circle of Willis. The objectives are to reduce the head of pressure playing upon the aneurysm and yet the maintenance of an adequate cerebral blood flow. The greater the resistance across the circle of Willis the greater will be the reduction of pressure at the

TABLE 4

*Calculated values assuming there is no change in the partition of blood flow through the cerebral hemispheres after ligation*

| | $R_{L'}=R_{R'}$ | $R_L$ | $R_R$ | Rc.w | $I_L=I_R$ | $\frac{Rc.w}{R_{L'}}$ 100 |
|---|---|---|---|---|---|---|
| S.P. | 2.8 | 3.5 | 2.3 | 1.2 | 27 | 43% |
| G.W. | 2.8 | 3.8 | 2.4 | 1.4 | 25 | 50% |
| L.J. | 4.2 | 6.1 | 2.7 | 3.4 | 18 | 81% |
| J.W. | 2.4 | 3.6 | 2.5 | 1.1 | 25 | 46% |

aneurysmal site but similarly the greater must be the adjustment of the vascular bed of the cerebral hemisphere on the side of the occluded carotid in order to maintain for itself an adequate blood flow. We can expect then, that in the older age group, as demonstrated by our 3rd patient (L.J.), the circle of Willis possibly being more sclerosed and rigid would introduce a relatively greater resistance to the circuit and cause a very effective fall in the head of pressure. However, the cerebral vascular bed, by the same token, would also be more rigid and thus even less able than normally to accommodate to the greater than usual fall in pressure head occasioned by the rigid circle of Willis. In such circumstances a marked reduction in blood flow through the cerebral hemisphere on the occluded side and the production of neurologic symptoms must be expected, and did occur in the 3rd patient.

That pressure and flow are related does not mean that one is a measure of the other. The efficacy of carotid ligation will be determined by the recording of its effects on the pressure in the occluded internal carotid artery; its safety will be determined by its effects on the cerebral blood flow.

## CONCLUSIONS

1. Cerebral circulatory studies done before and after ligation of a common carotid vessel revealed a marked increase in the cerebrovascular resistance after ligation.

2. The cerebral blood flow was maintained at normal levels in 3 patients who demonstrated no clinical effects as a result of ligation. In 1 patient who became hemiparetic and comatose following ligation of the left common carotid artery, the cerebral blood flow fell to an abnormally low level, the cerebrovascular resistance was markedly increased and the cerebral oxygen consumption was markedly reduced.

3. From a careful consideration of the data available it was concluded that in all cases the resistance across the circle of Willis after common carotid ligation was considerable and it was particularly high in the patient who became hemiplegic.

4. The two objectives of carotid ligation in the treatment of intracranial aneurysm, the reduction of the pressure head playing upon the aneurysmal site and the avoidance of neurological sequellae, are in a measure mutually antagonistic and depend upon the resistance introduced into the circulation by the circle of Willis. Pressure measurements in the occluded internal carotid artery will determine the efficacy of the carotid ligation, but its safety will be determined by its effects on the cerebral blood flow.

We wish to acknowledge the cooperation of Dr. J. C. Yaskin, Chief of Neurologic Service, and Dr. R. A. Groff, Chief of Neurosurgical Service, Graduate Hospital, in making the clinical material available to us.

## REFERENCES

1. Bouckaert, J. J., and Heymans, C. On the reflex regulation of the cerebral blood flow and the cerebral vaso-motor tone. *J. Physiol.*, 1935, *84:* 367–380.
2. Kety, S. S., and Schmidt, C. F. The nitrous oxide method for the quantitative determination of cerebral blood flow in man: theory, procedure and normal values. *J. clin. Invest.*, 1948, *27:* 476–483.
3. Peters, J. P., and van Slyke, D. D. Quantitative clinical chemistry. *Baltimore: Williams & Wilkins Co.*, 1931–32, *2:* (see pp. 283, 321).
4. Pilcher, C., and Thuss, C. Cerebral blood flow: III and IV. *Arch. Surg., Chicago*, 1934, *29:* 1024–1038 (see p. 1035).
5. Rein, H. Ueber Besonderheiten der Blutzirkulation in der Arteria carotis. *Z. Biologie*, 1929, *89:* 307–318.
6. Schneider, M., and Schneider, D. Untersuchungen über die Regulierung der Gehirndurchblutung. I. Mitteilung. II. Mitteilung: Einwirkung verschiedener Pharmaca auf die Gehirndurchblutung. *Arch. exp. Path. Pharmak.*, 1934, *175:* 606–639; 640–664.
7. Shenkin, H. A., Harmel, M. H., and Kety, S. S. Dynamic anatomy of the cerebral circulation. *Arch. Neurol. Psychiat., Chicago*, 1948, *60:* 240–252.
8. Sweet, W. H., and Bennett, H. S. Changes in internal carotid pressure during carotid and jugular occlusion and their clinical significance. *J. Neurosurg.*, 1948, *5:* 178–195.

# OBSERVATIONS ON THE INTERRELATIONSHIPS OF INTRACRANIAL PRESSURE AND CEREBRAL BLOOD FLOW*

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DURING the development of a method for recording continuously the intracranial pressure of rhesus monkeys, we observed that changes in hemodynamics have a profound influence on the intracranial pressure. The present communication deals with the experimental evidence which shows that the rate of intracranial blood flow is one of the important variables determining the intracranial pressure.

## MATERIALS AND METHODS

Our observations are derived from acute experiments on rhesus monkeys anesthetized with intravenous nembutal. The intracranial and spinal fluid pressures were measured by methods which have been described elsewhere.[2] The superior or inferior caval pressures were obtained by inserting a plastic catheter into the vessel through the internal jugular or the femoral vein. Regurgitant flow and clotting of blood in the catheter were obviated by a constant leak of heparinized saline under high pressure into the catheter. The position of the catheter was verified in vivo by the pressure obtained, and at autopsy by inspection. The pressure in the abdominal aorta was obtained by inserting a similar catheter through the femoral artery.

Changes in intracranial volume were induced by injecting oil into the extradural space through a tap screwed into the skull, or into the intracerebral substance through a needle inserted into the frontal or occipital pole on the side opposite the insertion of an intracerebral balloon needle. Saline was added to the cerebrospinal fluid and cerebrospinal fluid was withdrawn through the ventricular needle or through a needle inserted into the lumbar subarachnoid space. Inflation of a cuff placed about the neck increased the intracranial venous blood volume by compressing the venous outflow from the head.

Changes in the cardiac output were estimated from the arterial pressure pulses. The cerebral blood flow was modified by occlusion of one or both carotid arteries, by modification of the cardiac output through vagal stimulation or section, by the inhalation or intravenous injection of various drugs,

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by the induction of hemorrhage following section of the aorta or inferior vena cava, by clamping the trachea, or by inducing changes in intracranial volume by adding oil and saline to the intracranial cavity. Changes in cerebral blood flow were not directly measured, but were inferred from the known or expected effects of the procedures used, and from the observed modifications in the recorded intracranial, sinus, caval and arterial pressures.

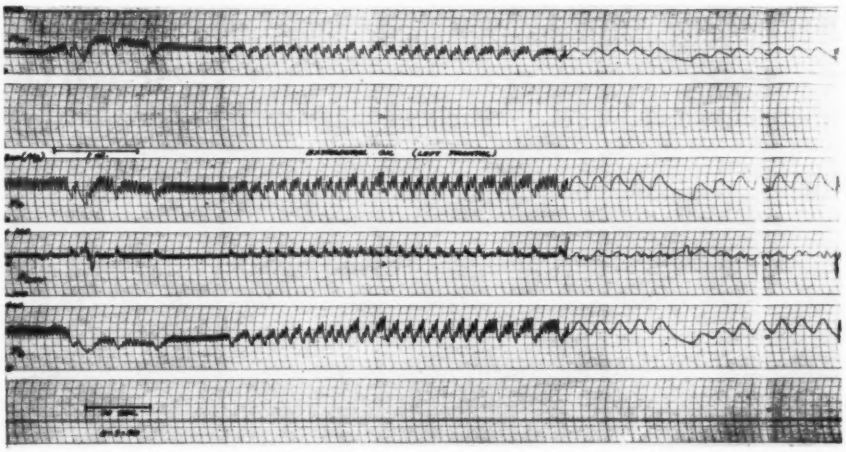

FIG. 1. Pressure responses to the intracranial introduction of oil.

The pressures in a needle in the lateral ventricle ($P_{IV}$) and catheters in the femoral artery ($P_A$), the inferior vena cava ($P_{CAV}$), and the sigmoid sinus ($P_S$) are recorded in mm. of water, except for $P_A$ which is in mm. of mercury. The paper speed was increased at the end to 6.25 times the initial speed.

The injection of oil causes an immediate pressor response in the ventricle and the artery. This response is complicated by heart block. The sinus response is depressor, follows the arterial pressure closely, and is independent of the caval pressure.

## OBSERVATIONS

*Intracranial Oil Injection.* The extradural or intracerebral injection of oil in the course of a few seconds causes a concomitant rise in intracranial pressure. The pressure falls, after a transient peak, to levels that remain somewhat higher than the initial level (Figs. 1, 2, and 3). As long as the cardiac output remains essentially unchanged, the further injection of equal volumes of oil causes disproportionately high increases in the pressure, and the intracranial pulse pressure becomes higher, and the usual respiratory variations in blood pressure more marked (Fig. 11). The continued injection finally causes such respiratory effects as irregular deep respiration or apnoea, and the induction of cardiac dysrhythmias and changes in form of the ventricular complexes of the electrocardiogram, with a fall in blood pressure. The intracranial pressure invariably falls with this fall in the blood pressure. The injection of further increments of oil causes a less marked and more

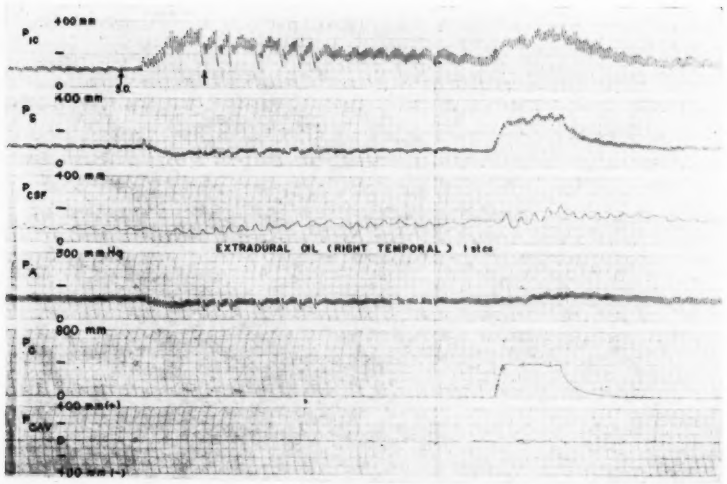


FIG. 2. Pressure responses to the intracranial introduction of oil.

The pressures in a balloon in the cerebral tissue ($P_{IC}$) and in a needle in the lumbar subarachnoid space ($P_{CSF}$) are recorded in channels 1 and 3. The pressure in an inflatable cuff around the neck ($P_C$) is recorded in channel 5. The other abbreviations are as in Fig. 1.

The pressure responses to the introduction of oil are similar to those of Fig. 1. The drop in lumbar subarachnoid pressure is unusual; the responses to cuff inflation are the usual ones.

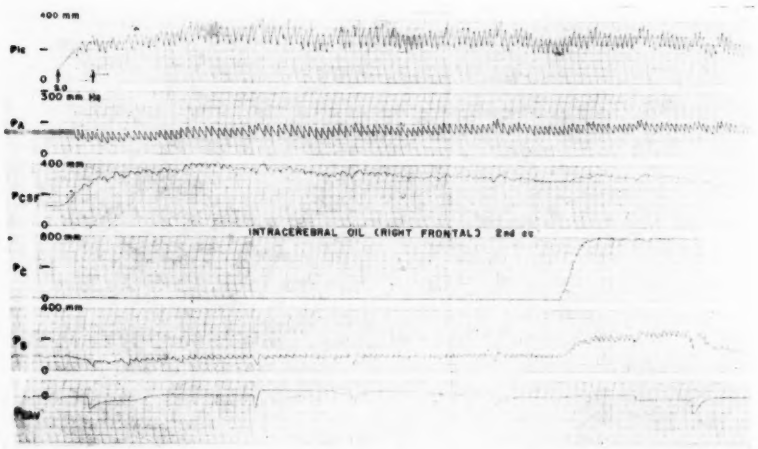


FIG. 3. Pressure responses to the intracranial introduction of oil.

The caval pressure ($P_{CAV}$) is complicated by an artifact.

The pressure responses to the intracerebral introduction of oil are similar to those following its extradural introduction. The increase in lumbar subarachnoid pressure is more usual than the response in Fig. 2.

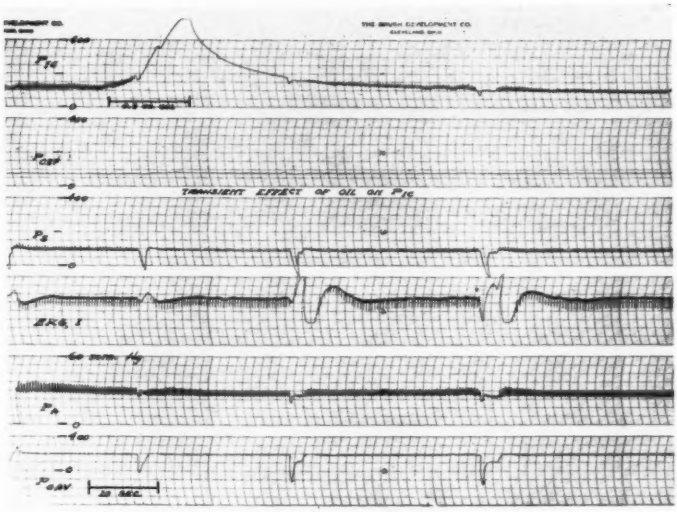


FIG. 4. Transient effect of oil in the dying animal.

The artifact in the electrocardiogram (EKG, I), is due to the respiratory movements of the animal. The cerebrospinal fluid pressure of rhesus monkeys is frequently not equivalent to the intracranial pressure, apparently because of fluid loss from leak around the needle puncture.

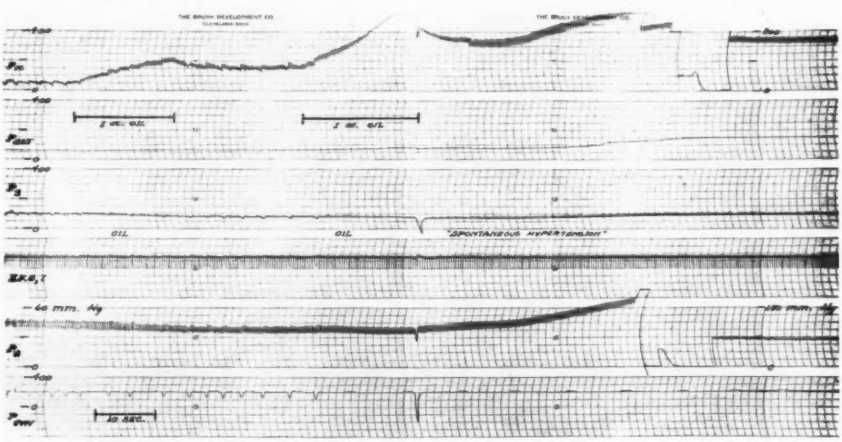


FIG. 5. "Spontaneous" hypertension following the introduction of oil.

While the usual transient responses of the pressures in the dying animal were being recorded, apnoea began and the arterial pressure suddenly rose. With this arterial pressor response, the intracranial pressure increased concomitantly.

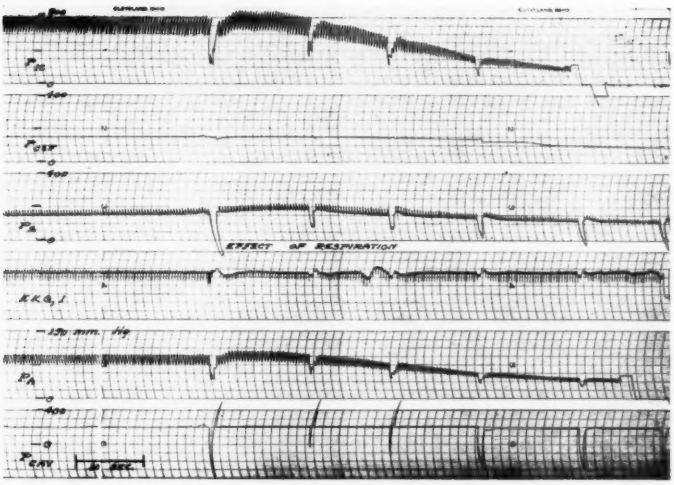


FIG. 6. Subsidence of "spontaneous" hypertension.

This tracing is of a portion of the record 3 minutes after Fig. 5. The intracranial, sinus, and arterial pressures vary concomitantly. Because clamping the trachea does not induce the responses of Figs. 5 and 6, presumably the apnoea and pressor responses are both due to central stimulation and are not dependent on each other.

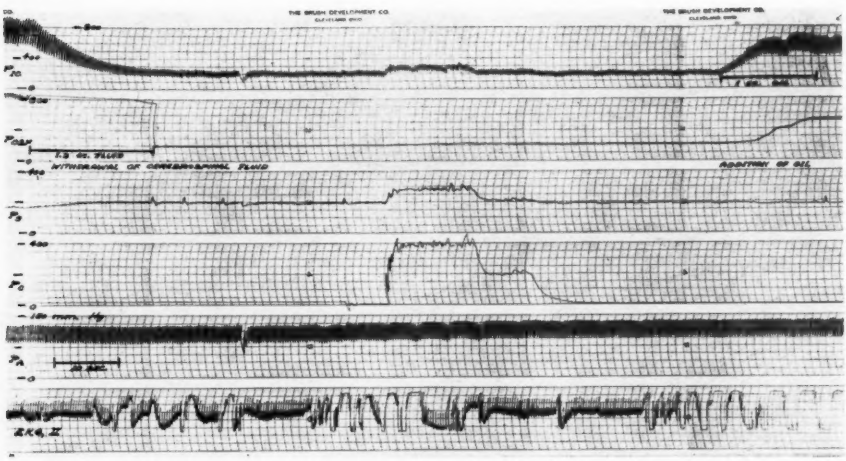


FIG. 7. Effect of the withdrawal of fluid from the lumbar subarachnoid space and the intracranial introduction of oil.

The sinus pressure varied inversely with the intracranial, lumbar and arterial pressures when fluid was withdrawn. The rise in intracranial pressure corresponded to the rise in sinus pressure resulting from an increase in pressure in the cuff around the neck.

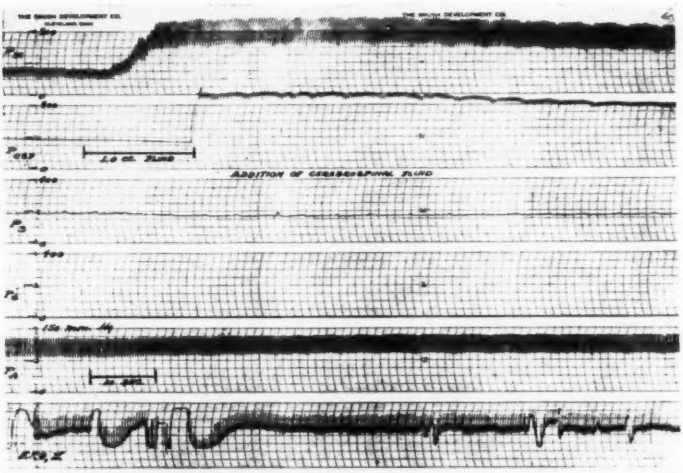


FIG. 8. Effect of the addition of fluid to the lumbar subarachnoid space.

This tracing follows a minute after that in Fig. 7. The pressure responses are the inverse of the previous ones.

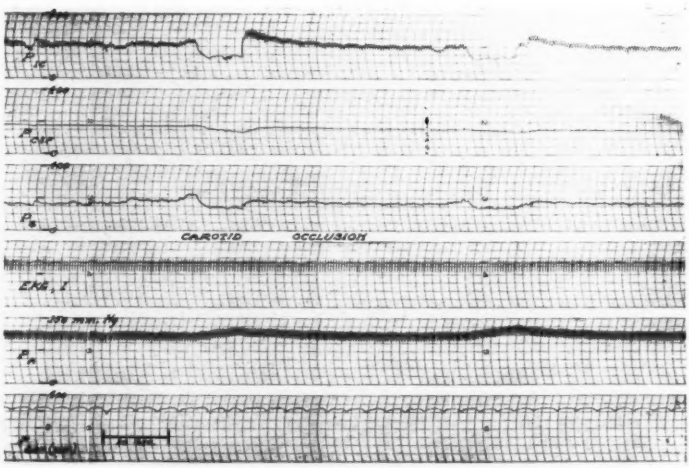


FIG. 9. Effect of the occlusion of both carotid arteries.

Both carotids were clamped high in the neck. The sinus pressure is influenced slightly by the manipulations associated with clamping the arteries. The slight and characteristic arterial pressor response to carotid occlusion is illustrated as well as the surge in intracranial pressure following release of the clamps.

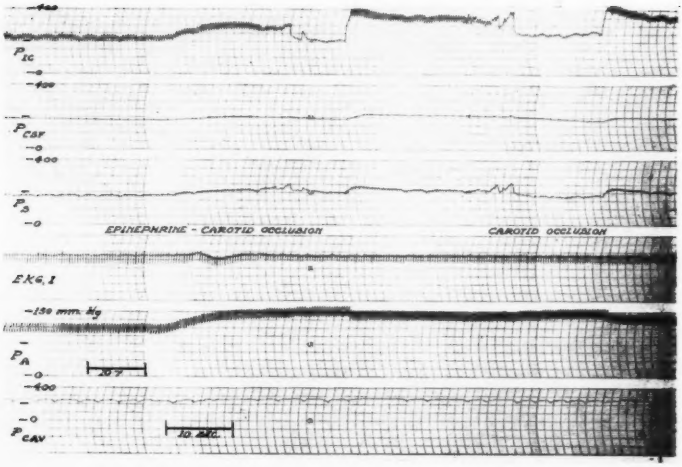


FIG. 10. Effect of occlusion of both carotid arteries after epinephrine injection. The effects of both procedures are independent, and additive.

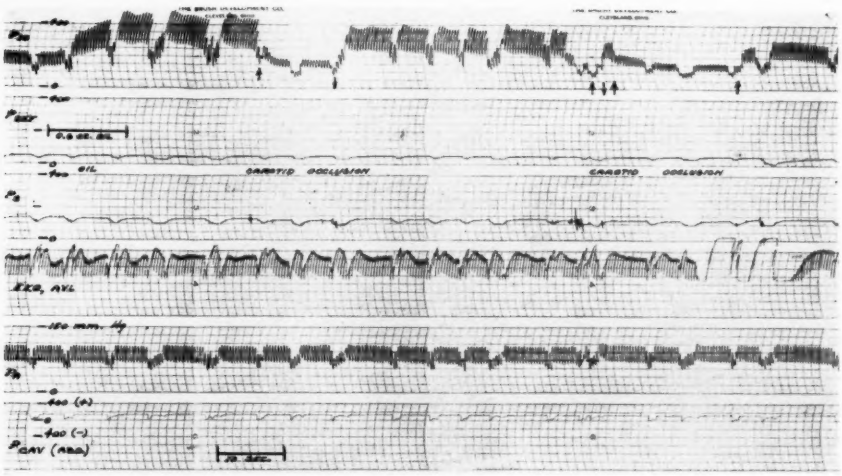


FIG. 11. Effect of occlusion of the carotid arteries after addition of oil.

The depressor effect of inspiration on the intracranial pressure is also more marked, the higher the intracranial pressure.

transient intracranial pressor response than it did initially (Fig. 4). When the heart fails to beat, the intracranial pressure decays to near zero.

Each time oil is injected and forces the intracranial pressure up, the sinus pressure falls, as long as the cardiac output remains essentially unchanged

(Figs. 1, 2 and 3). If the cardiac output varies, the sinus pressure varies in the same direction. However, if the superior caval pressure rises as a result of a procedure, the sinus pressure fails to fall below this pressure, even if the cardiac output continues to fall (Fig. 14).

The injection of saline into the ventricle and the injection into and withdrawal of saline from the spinal subarachnoid space cause similar pressure responses (Figs. 7 and 8).

Usually after several cc. of oil have been added, the further injection

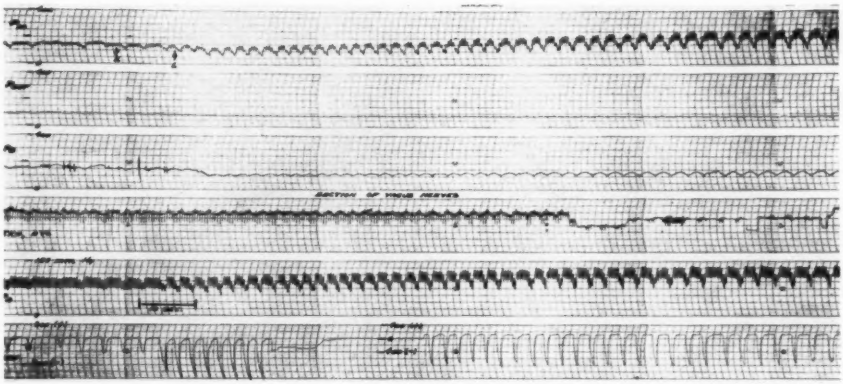

FIG. 12. Effect of bilateral vagal section.

$P_{CAV}$ is the pressure in the superior vena cava. The bilateral vagotomy induced bilateral adductor paralysis, so the response is complicated by anoxic anoxia and hypercapnia.

of oil is followed in about 15 seconds by the development of marked arterial hypertension. This arterial pressor response is associated with apnoea and marked rises in intracranial and sinus pressures. The return of the intracranial and the arterial pressures to the preinjection level, and the resumption of normal respiration, occur concomitantly after several minutes. Such responses have not been induced by clamping the trachea (Figs. 5 and 6).

*Carotid Occlusion.* Occlusion of either carotid artery drops the intracranial pressure and pulse pressure immediately. This effect is the greater, the higher the intracranial pressure. Occlusion of both carotids causes a more profound effect, and may drop greatly elevated intracranial pressures to nearly normal, the residual pressure presumably being dependent upon the flow maintained through the vertebral arteries (Figs. 9, 10 and 11). There is an associated drop in sinus pressure, unless the manipulations in the neck impede the cerebral venous outflow.

*Vagal Stimulation or Section.* The response to stimulation of the vagus nerve depends on the effect of this procedure on the cardiac output and the airway. The arterial and intracranial depressor responses follow each other intimately. Section of both vagi high in the neck without a tracheotomy

tube in place, causes profound changes in the superior caval pressure. The forced inspiration against the closed glottis leads to caval pressures as low as −50 mm. of mercury. Corresponding to these low intrathoracic pressures there are equivalent drops in the femoral arterial pressure, and the sinus and intracranial pressures reflect these changes in cardiac output (Fig. 12).

*Effect of Drugs.* Epinephrine: The intravenous injection of epinephrine (5 μgm.) causes transient pressor responses in the arterial, intracranial and sinus pressures. Slightly larger doses (10 μgm.) usually induce a vagal re-

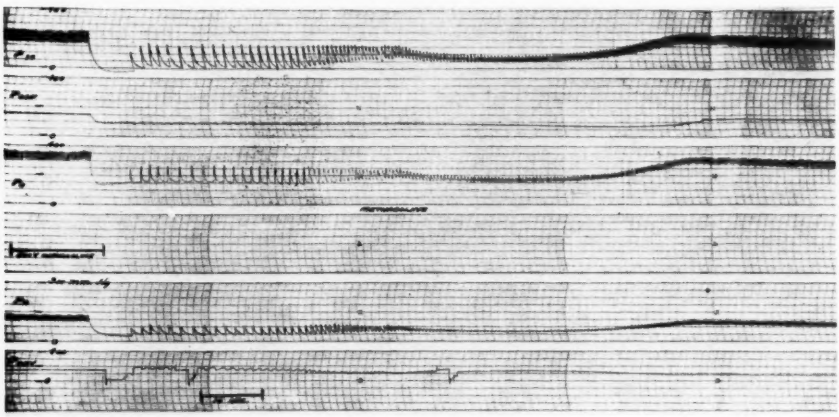

FIG. 13. Effect of intravenous methacholine.

There is a dramatic association among the depressor responses in the intracranial, sinus and arterial pressures. The caval pressure recording is complicated by artifact in the smooth portions of the curve.

sponse, with cardiac slowing (Figs. 10 and 15). The ultimate result of the drug on the pressures depends upon the net effect on the cardiac output of the increase in pressure and the bradycardia. When arterial depressor effects result from epinephrine, the intracranial pressure response is depressor.

Histamine: Intravenous histamine in the doses used causes a depressor arterial response, and an increase in pulse pressure. Both the sinus and intracranial pressures show a transient pressor response (Fig. 15).

Methacholine: The fall of the intracranial and sinus pressures after the intravenous injection of methacholine depends on the extent of the depressor arterial effect. The fall in intracranial and sinus pressures as a result of the consequent reduction in cerebral flow may be marked; and yet if the intracranial pressure is initially low at the time the drug was injected, and the superior caval pressure is increased by the exhibition of the drug, there may be an increase in both the intracranial and sinus pressures (Figs. 13 and 14).

Hypoxia and hypercapnia: Clamping of the trachea causes a depressor response in all three of these pressures. On the several occasions in which this procedure has been done, it has not been observed to cause the appar-

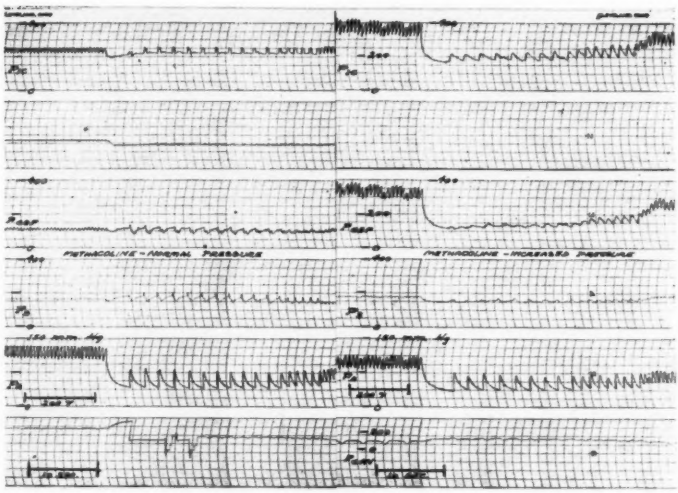


FIG. 14. Effect of intravenous methacholine.

The marked depressor responses of the intracranial and sinus pressures shown in Fig. 13 and the last half of Fig. 14 are conditioned by the pressor response in the vena cava, for the two former pressures do not fall below the caval pressure.

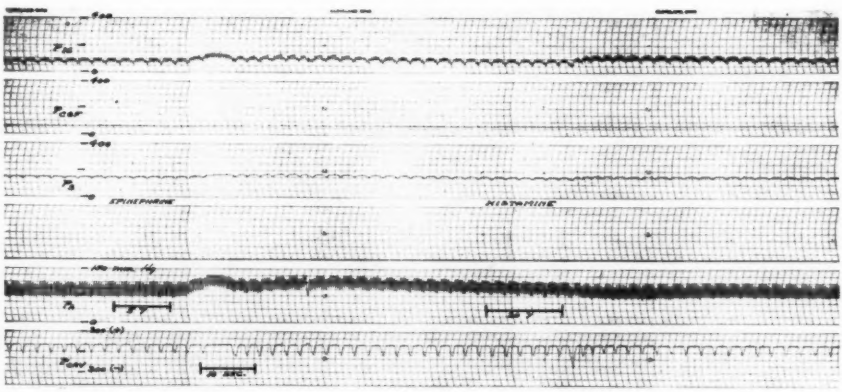


FIG. 15. Response to intravenous epinephrine and histamine.

Both drugs have a slight pressor effect on the intracranial and sinus pressures, even though epinephrine has a pressor and histamine a depressor effect on the arterial pressure.

ently spontaneous hypertension noted above that not infrequently follows shortly after the injection of intracranial oil, as in Figs. 4 and 5.

Hemorrhage: Section of the aorta or abdominal cava, with unchecked hemorrhage, causes a depressor response in all three variables (Figs. 16 and 17).

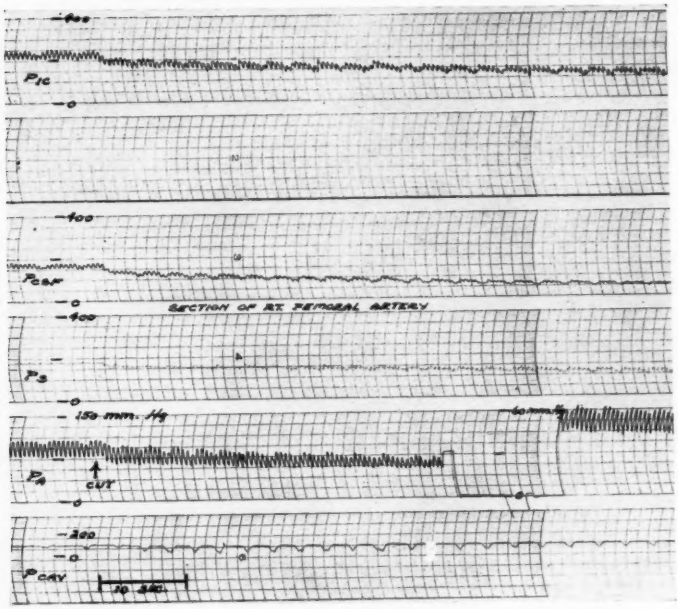


FIG. 16. Effect of continued hemorrhage following arterial section.

The response of all five pressures is depressor.

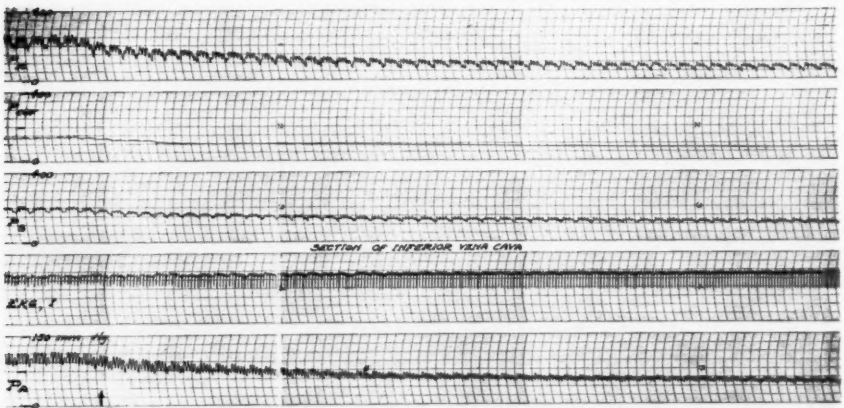


FIG. 17. Effect of continued hemorrhage following caval section.

The depressor responses are the same whether the hemorrhage is arterial or venous.

## DISCUSSION

The effects of various drugs on the lumbar subarachnoid fluid pressure have been well documented in the literature.[1,3] The traditional explanations for the acute responses classify them as resulting from venous pressure influences or from active changes in the caliber of the cerebral vessels.

Epinephrine, for example, is known to cause an increase in venous pressure. Figs. 10 and 15 illustrate the intracranial, sigmoid sinus, arterial and lumbar subarachnoid pressor responses to its intravenous injection. It may be observed that the higher the initial intracranial pressure, the greater is the effect of the drug. An intracranial pressure increase from 240 to 320 mm. of water cannot be ascribed to the venous back pressure effect resulting from a rise in sinus pressure from 180 to 220 mm. of water.

In the acute experiments we have performed, the changes in intracranial pressure usually have varied with the arterial pressure. Histamine drops the arterial pressure and epinephrine raises it (Fig. 5), yet both drugs increase the intracranial pressure; therefore, the intracranial pressure responses are not due simply to pressures transmitted directly through the walls of the cerebral arteries and arterioles.

The one variable with which the intracranial pressure varies concomitantly in such experiments as the exhibition of these drugs and the clamping of both carotids, is the volume flow of blood into the cranium. The intimate correspondence between the intracranial pressure pulses and the arterial pulses is another example of the dependence of intracranial pressure on cerebral blood flow.

The pressure in the great veins may be the controlling influence on the intracranial pressure response, if the venous pressure is sufficiently high. The intracranial pressure increases when the venous outflow from the head is constricted, as by a cuff about the neck (Figs. 2, 3, and 7). It also does not fall when the cardiac output is reduced acutely by methacholine injection, if the rise in superior caval pressure is great enough to passively support the intracranial pressure (Fig. 14).

The characteristic and progressively different responses of the intracranial pressure to the intracranial injection of oil have already been outlined. As mentioned, the arterial pressure and cardiac output may suddenly increase dramatically within a minute after the injection of oil has been discontinued. Under these conditions the intracranial pressor response is equally dramatic, and is maintained as long as the cardiac output remains elevated. The intracranial pressor response, far from causing a decrease in cerebral flow, is indirectly due to an increase in flow. These experiments indicate that the rate of cerebral blood flow is quite as important as the volume of a space-occupying intracranial lesion, in maintaining elevated intracranial pressures. When the cardiac output falls the intracranial pressure is not maintained, no matter the size of the space-occupying intracranial lesion.

The reflex increases in cardiac output coming occasionally after the intracranial injection of oil are usually associated with apnoea, and when breath-

ing recommences the arterial pressure usually falls. In our limited experience, clamping the trachea does not induce these responses. Both experimental conditions induce hypercapnia and anoxic anoxia. Their opposite effects on the intracranial pressure indicate that these chemical stimuli are variables whose control of the intracranial pressure and rate of cerebral blood flow may be overcome by more powerful reflex stimuli.

## CONCLUSIONS

1. A principal variable controlling the intracranial pressure of rhesus monkeys is the rate of intracranial blood flow.

2. The volume of fluid added to the brain substance or the cerebrospinal fluid space is also of great importance, but pressor responses to the injection of fluid are not maintained unless the rate of cerebral blood flow is maintained.

3. Both the arterial blood pressure and the cardiac output may influence the rate of cerebral blood flow and therefore the intracranial pressure, but neither has a direct influence on the intracranial pressure.

4. The normal intracranial pressure is supported by back pressure from the great veins, which may or may not reflect intrathoracic and intracardiac pressures. This back pressure is usually an unimportant variable in causing or maintaining *high* intracranial pressures.

5. Relaxation of the walls of the intracranial capillary-venous bed, produced by direct chemical action on these vessels or produced reflexly, cannot release the force necessary to increase the intracranial pressure to the extent recorded in these experiments. A suggested, as yet hypothetical, mechanism that better explains our observations is the following: The increase in intracranial pressure results from an increase in intracranial, intravascular volume, attendant on the increase in cerebral flow, which is secondary to changes in cerebral arteriolar resistance or pressure.

6. Reflex effects far more powerful than anoxia and hypercapnia may at times influence the intracranial pressure through their effect on the cerebral blood flow.

7. Under certain conditions, the sigmoid sinus pressure, the intracerebral and ventricular pressures, and the lumbar subarachnoid fluid pressures may be used to indicate directional changes in the rate of flow of intracranial blood.

## REFERENCES

1. Merritt, H. H., and Fremont-Smith, F. The cerebrospinal fluid. *Philadelphia: W. B. Saunders Co.*, 1937, 333 pp. (see p. 50).
2. Ryder, H. W., Espey, F. F., Kristoff, F. V., Lamb, D. H., and Evans, J. P. The relation of pressures in the intracranial cavity, the sigmoid sinus and the extracranial subarachnoid space in rhesus monkeys. (To be published.)
3. Schmidt, C. F. The cerebral circulation in health and disease. *Springfield, Ill.: Charles C Thomas*, 1950, v, 78 pp.

# SURGICAL EXPERIENCES WITH ARTERIOVENOUS ANOMALIES OF THE BRAIN*

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IT IS A matter of record that there is no more formidable lesion dealt with by the neurologic surgeon than the arteriovenous anomalies encountered in the brain. In the first comprehensive work on this subject, Cushing and Bailey[1] were extremely dubious as to whether or not these lesions would ever be amenable to direct surgical therapy. However, as better methods of hemostasis were developed through the evolution of the electrosurgical unit, reports appeared demonstrating the feasibility of therapeutic attack. Dandy,[2] Norlén,[3] Olivecrona,[4] Pilcher,[5] Ray,[6] and Trupp and Sachs[7] have made available their experience with the angiomas.

These abnormal remnants of the rapidly changing embryonic circulation of the developing brain usually come to the attention of the clinician during the late second and third decades of life although they do occasionally become symptomatic before that time. The usual story is one of the development of focal fits which gradually increase in frequency and severity, becoming generalized and often uncontrolled with more than adequate medical therapy. The development of headaches of increasing frequency and severity and, in our experience, repetitive episodes of subarachnoid hemorrhage are the next most common symptoms and signs in that order. Hemorrhage may also be intracerebral and in such an instance usually produces irreversible damage.

The greatest factor facilitating surgical treatment of these lesions has been the introduction and development of angiographic techniques. Precise localization and, most important of all, demonstration of major afferent arterial components are usually clearly defined. This is particularly important when the angioma is situated in the dominant hemisphere or in the depths of the brain in a position not favoring direct attack upon the lesion. Routine roentgenograms of the skull may frequently demonstrate an associated anomalous blood supply to the skull itself associated with the underlying vascular anomaly of the cortex (Fig. 1). These lesions also have a characteristic defect demonstrable by pneumography. Olivecrona[4] has pointed out the importance of focal atrophy demonstrated by air study in the absence of other roentgen findings, particularly when the evidence for atrophy is associated with focal neurological signs compatible with such a lesion. In this group of cases air study in most instances was undertaken without the true nature of the lesion being suspected. Aside from the atrophy

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as mentioned, these lesions present a typical bizarre type of deformity (Figs. 4, 5, 10, and 13).

Our experience with the arteriovenous anomalies of the brain is represented by the following 18 cases.

## REPORT OF CASES

*Case 1.* C.P. was a 30-year-old white male admitted to the University Hospital on April 25, 1939 with the complaints of headache increasing in frequency and severity and Jacksonian fits involving the left hand and leg, the latter having begun 1 year previously, increasing in frequency and severity. Pertinent findings were bruit over the right parietal eminence and low-grade papilledema. A right parietal flap was turned down revealing an extensive angiomatous deformity on the surface of the right parietal lobe. Multiple surface ligations were done with silk and silver clips. Electrocoagulation of the available vessels was carried out. No attempt was made to dissect out the anomaly. A left hemiparesis was present postoperatively; however, the bruit was entirely gone and was still absent 2 months later. The hemiparesis completely disappeared and has not recurred. He continues to have an occasional seizure.

*Case 2.* B.C. was an 8-year-old white female admitted on Oct. 6, 1939 with a story of persistent headaches and vomiting since infancy. There was a bluish discoloration over the left frontal bossa. There had been numerous nosebleeds. One year previously the patient had had a subarachnoid hemorrhage. Two weeks prior to admission she had onset of severe, almost constant, right Jacksonian fits, recurrence of severe nosebleeds, and gradual lowering of consciousness and development of a right hemiparesis. There was a definite tumescence of the left frontal bossa, the eyelids, and the left side of the nose. A tangle of abnormal vessels was demonstrable in the retinal circulation on the left. There was a right hemiparesis. On Oct. 26, 1939 ligation of the left common and external carotid arteries was done and on Nov. 13, 1939 the left middle cerebral artery was partially occluded with silver clips. Her symptoms remained more or less unabated. She became progressively worse. Her hemiparesis became a total hemiplegia, headaches increased and fits persisted. She had become more or less vegetative as far as her mentality was concerned. She was last seen on Dec. 16, 1946, a helpless invalid.

*Case 3.* C.W. was a 37-year-old white male admitted on Oct. 29, 1941 with the story that he had had headaches as long as he could remember and during the 3 preceding years had had onset of left Jacksonian attacks involving both the arm and leg and visual disturbances in the left homonymous field. The fits could not be controlled with medication. Pertinent findings were a mild left hemiparesis, a definite bruit over the right occipital parietal region, and a left homonymous hemianopia. Routine x-rays of the skull demonstrated a typical calcified lesion (Fig. 1). On Oct. 30, 1941, a total ligation of the right internal carotid artery was done. He was last seen on Dec. 6, 1941. There was a marked diminution of bruit; hemianopia and hemiparesis were still present. Headaches were absent and the fits were better controlled on medication. Attempts at follow-up have been unsuccessful.

*Case 4.* W.W. was a 30-year-old white male admitted on Dec. 17, 1942, having

had Jacksonian fits involving the arm and leg on the right, and headache, increasing in frequency and severity, for 6 years. Seizures were uncontrolled by medication. There was a bruit over the left carotid artery behind the angle of the jaw. An arteriogram on Dec. 24, 1942 demonstrated the lesion seen in Fig. 2, and on Jan. 14, 1943 ligature of the common, external and internal carotid arteries was done. There were no complications to this procedure. He was last seen on May 24, 1943. He had had only 4 fits in the interim and was very well controlled on medication. Follow-up to date has been unsuccessful.

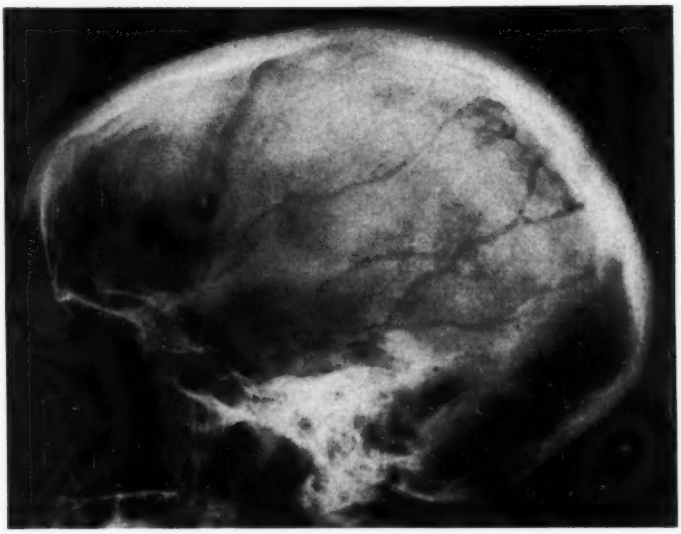

FIG. 1. *Case 3.* Routine lateral exposure showing excessive vascularization of skull and calcification at right parieto-temporal-occipital confluence.

*Case 5.* O.M. was a 12-year-old white male admitted on Dec. 19, 1944. One week previously he had sudden onset of coma and a right hemiparesis; both gradually improved with the exception that the foot and lower leg were still paretic. Subarachnoid and intracortical hemorrhage was diagnosed. Routine x-rays of the skull were normal. An arteriogram demonstrated an anomaly of the left anterior cerebral circulation (Fig. 3). On Jan. 2, 1945 a left pituitary flap was turned down and the left anterior cerebral artery was isolated by silver clips, above the anterior communicating artery. He has been followed intermittently since that time and has no neurologic residuals.

*Case 6.* W.B. was a 50-year-old white male admitted on Aug. 2, 1945. For 6 months he had had progressive headache and dizziness. The week before admission he had marked increase in his symptoms, had become aphasic and drowsy, and had undergone marked personality change. On examination an expressive aphasia was demonstrated. There was marked weakness of grip in the right hand and he was

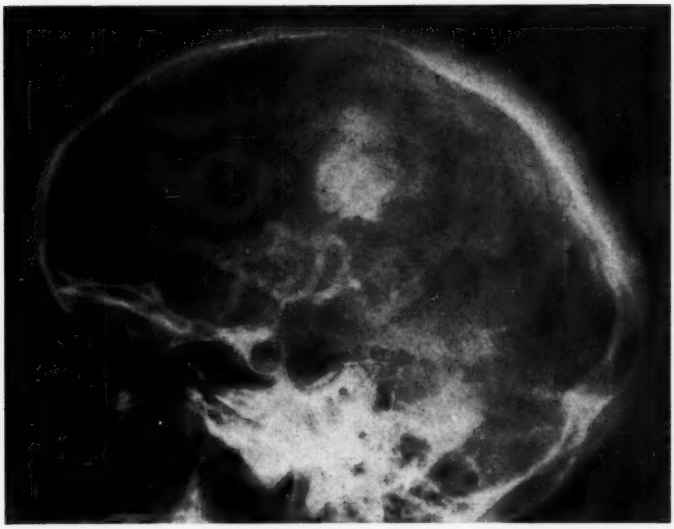

FIG. 2. *Case 4.* Lateral angiogram showing left parietal anomaly with major afferent components arising from the middle cerebral artery.

quite stuporous. Routine x-rays of the skull were normal. A ventriculogram demonstrated a left posterior frontal space-taking lesion. At operation on Aug. 20, 1945 there was marked xanthochromic staining of the cortex. A walnut-sized subcortical hemorrhage was found associated with an angiomatous deformity of surface vessels. All feeding and draining vessels were ligated and the lesion was totally excised. Postoperative epilepsy ensued but was easily controlled by medication. He has been followed intermittently since that time and has no neurologic residuals.

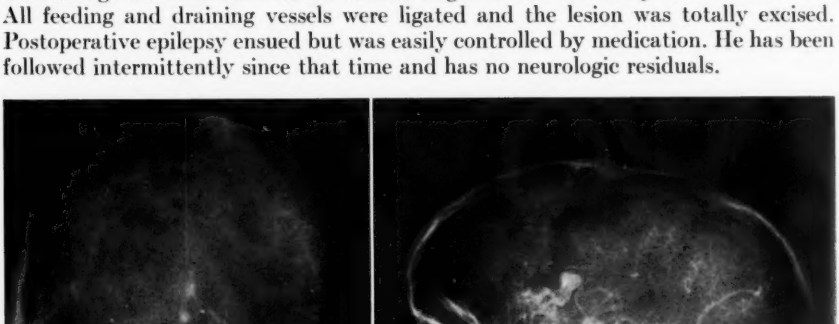

FIG. 3. *Case 5.* Anterior and lateral angiograms of left frontal anomaly of the anterior cerebral system. Drainage is through the vein of Galen.

*Case 7.* C.P. was a 41-year-old white male admitted on Jan. 4, 1946 with an 18 months' history of petit mal fits gradually becoming more severe. One week prior to admission he had a grand mal seizure and had remained confused. On examination the patient was drowsy, complained of photophobia and had marked stiffness of the neck. There was low-grade papilledema. X-ray of the skull revealed calcification in the right posterior inferior frontal region. Ventriculogram demonstrated a space-taking lesion in this region (Fig. 4). A right frontal flap was turned down on Jan. 15, 1946 in such a way as to expose the medial surface of the frontal lobe, where a large

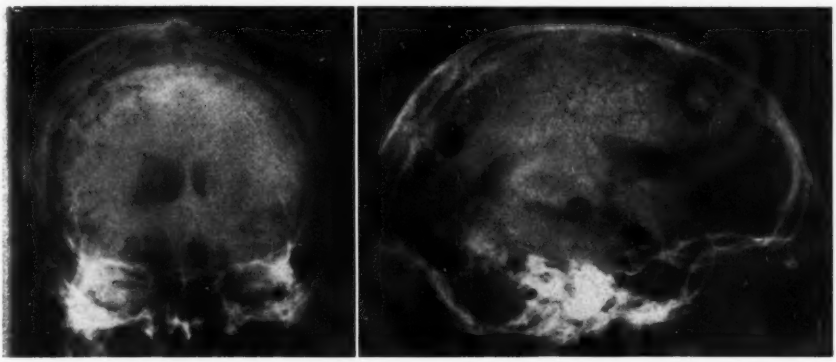

FIG. 4. *Case 7.* Frontal and lateral pneumograms showing calcification in the midline just below the tips of both frontal horns, with filling defect of these structures plus atrophy as suggested by minimal dilatation of the ventricles.

arteriovenous angioma was encountered. Several large aneurysmal dilatations were ligated and the entire anomaly was removed following multiple ligations and coagulation. He has no neurologic deficit and has had no more fits although he was given medication for only 2 years postoperatively.

*Case 8.* R.K. was a 29-year-old white female admitted on July 9, 1946. Three months previously she had had a subarachnoid hemorrhage associated with left hemiparesis which had been complete. As her acute signs subsided the hemiplegia completely disappeared. She had uncontrolled epilepsy on a program of adequate medication. Arteriogram demonstrated a right frontal polar angioma. On July 11, 1946 this lesion was removed in toto. The patient expired suddenly on the 3rd postoperative day. It was believed that the cause of death was massive cerebral edema resulting from injudicious use of parenteral fluids.

*Case 9.* E.A. was an 18-year-old white male admitted on Oct. 5, 1946. His story was one of increasingly severe and uncontrollable Jacksonian fits involving primarily the left arm and present since age 16. He also had headaches of increasing frequency and severity. Upon admission he was stuporous and had a left hemiparesis. Brain tumor was suspected and ventriculogram demonstrated an anterior parasagittal space-taking lesion (Fig. 5). A bifrontal flap was turned down on Oct. 23, 1946 exposing a large angioma situated on the medial surface of the frontal lobe, running on to the corpus callosum. The right anterior cerebral artery was ligated, producing almost total collapse of the lesion which was then completely removed.

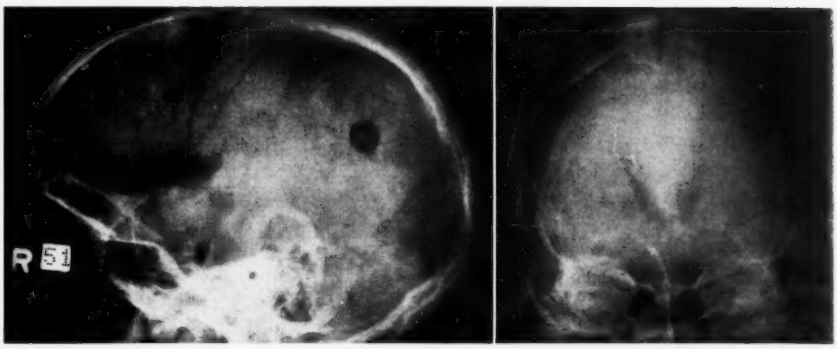


FIG. 5. *Case 9.* Ventriculogram showing bizarre frontal parasagittal defect created by large angioma on medial surface of right frontal lobe and anterior corpus callosum.

He was last seen on Jan. 12, 1948. He had been on anticonvulsant medication and although there was no neurological deficit, he was having a "light" fit about once a month.

*Case 10.* G.L. was a 34-year-old white woman admitted on Mar. 18, 1947 with the history of having had Jacksonian fits for several years. One week previously she had become comatose, remaining so for 2 or 3 hours. The coma had been preceded by severe pain behind the right eye. Arteriogram demonstrated the lesion seen in Fig. 6. On Apr. 14, 1947 a left parietal flap was turned down and the lesion was removed in toto. Except for a minor defect in stereognostic sensibility of the right hand, she has no neurological deficit 3 years later. Her seizures are well controlled on a regimen of anticonvulsant medication.

*Case 11.* L.J. was a 32-year-old white male admitted on Apr. 18, 1948. Two years before, he had had sudden nocturnal onset of intracerebral and subarachnoid

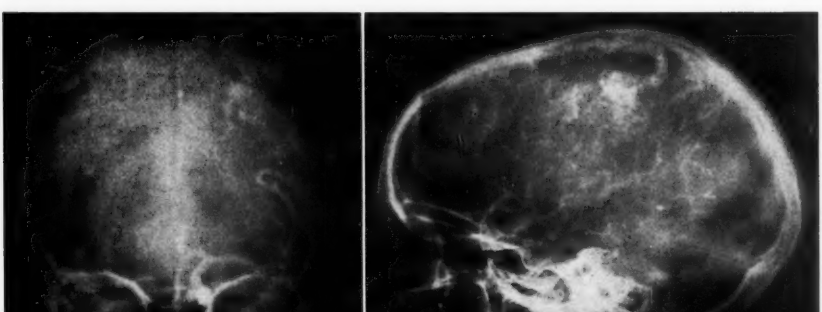

FIG. 6. *Case 10.* Frontal and lateral angiograms showing superficial left parietal anomaly of the middle cerebral system. Spill is through the superior longitudinal sinus.

hemorrhage, following which he was totally aphasic and had a right hemiplegia. The hemiplegia cleared completely within 6 weeks; however, the aphasia remained profound although improvement was still gradually occurring at the time of admission. Grand mal epilepsy developed, the fits beginning as a right Jacksonian march involving the face, hand and leg before becoming generalized. They were not controlled on anticonvulsant medication. Angiogram demonstrated a large angioma situated in the left Sylvian fissure (Fig. 7). On Apr. 20, 1948, a left-sided

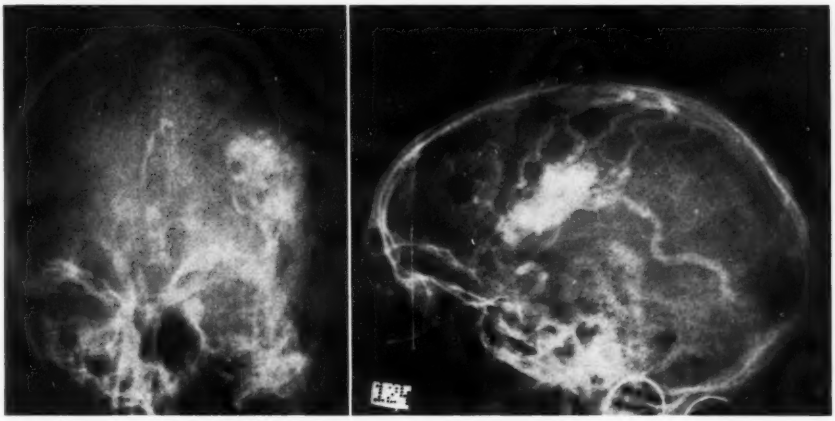

FIG. 7. *Case 11.* Frontal and lateral angiograms showing huge anomaly of the left Sylvian circulation. Major afferent components arise from the middle cerebral artery. Major drainage is superficial to the superior longitudinal sinus and deep through the vein of Galen.

pituitary flap was turned down and by arachnoidal dissection the major afferent trunks to this angioma arising from the left middle cerebral artery were isolated and ligated. The patient has been seen at frequent intervals since discharge. He is still partially aphasic, although speech continues to improve with training. His seizures are now easily controlled with medication.

*Case 12.* L.B. was a 25-year-old white female admitted on Sept. 2, 1946. She had had 3 episodes of subarachnoid hemorrhage in the preceding 6 years. A right arteriogram demonstrated a midline anomaly situated in the corpus callosum. The patient was having headache at that time but since this could be controlled with mild anodynes no further therapy was advised. She returned 2 years later on Apr. 19, 1948, with the story that her headaches were unbearable and almost constant. She had had 2 episodes of numbness involving the right arm and leg. A *left*-sided arteriogram was then performed demonstrating again the midline callosal lesion (Fig. 8) with its major afferent components arising from each anterior cerebral artery. On May 3, 1948 a 6-hole flap straddling the midline over the vertex was lifted and the afferent trunks from the anterior cerebral vessels on both sides were ligated. What could be seen of the angioma shrank considerably following ligation of the last of the afferent components. This structure was then further thrombosed with the electrosurgical unit. The patient has been seen frequently since discharge and has had no more

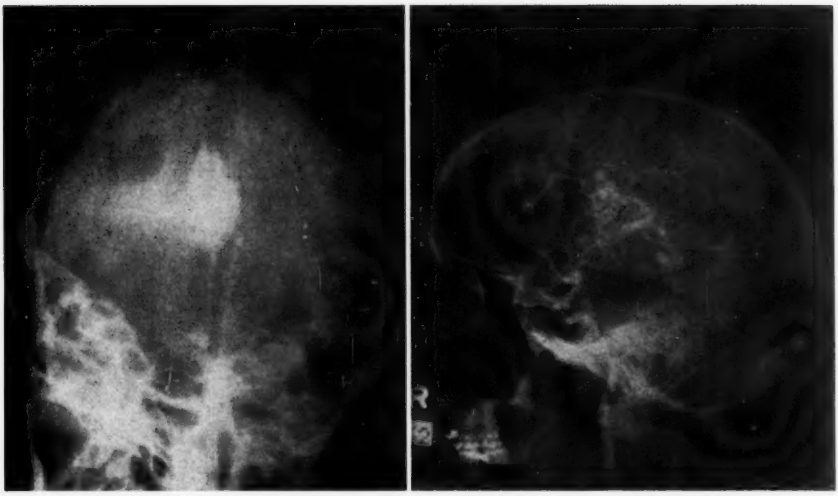

FIG. 8. *Case 12.* Frontal and lateral angiograms showing midline anomaly situated in corpus callosum and medial surface of both hemispheres. Afferent components are from both anterior cerebral systems. Total spill seems to be via great vein of Galen.

headache. She had 1 major seizure following surgery. She has been on a minimal program of anticonvulsant medication since without attacks.

*Case 13.* B.B. was a 40-year-old white male admitted on Sept. 12, 1948. Twelve hours before, he had had sudden onset of right-sided headache associated with temporary loss of consciousness. Upon awakening he had a profound left hemiplegia. He also had bloody CSF, papilledema and a left homonymous hemianopia. X-ray films showed a pineal shift of 2 mm. to the left. An arteriogram demonstrated a

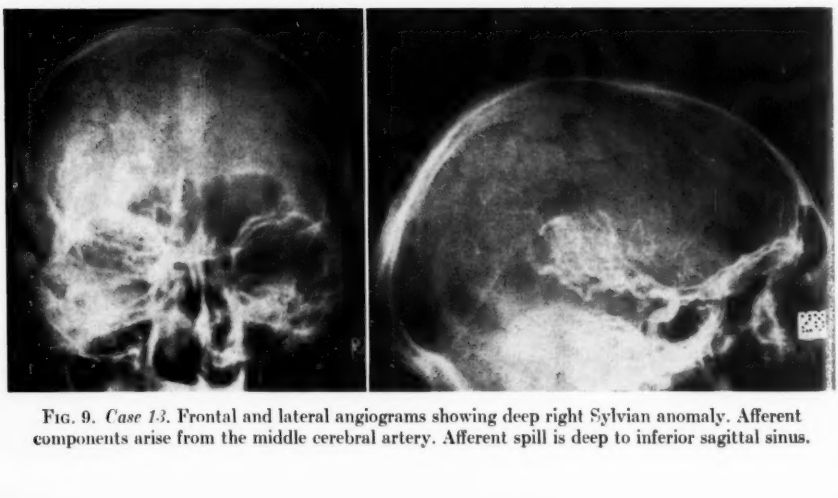

FIG. 9. *Case 13.* Frontal and lateral angiograms showing deep right Sylvian anomaly. Afferent components arise from the middle cerebral artery. Afferent spill is deep to inferior sagittal sinus.

large, deep Sylvian vascular anomaly (Fig. 9), which was approached on Nov. 9, 1948 by turning down a right-sided pituitary flap. By arachnoidal dissection the major afferent components arising from the right middle cerebral artery were exposed and ligated. A good bit of the mass could be seen over the anteromedial portion of the temporal and parietal lobes and was thrombosed and shrunk down with the electrosurgical unit. A spastic left hemiplegia persists. He has, however, had no fits on a program of anticonvulsant medication.

FIG. 10. *Case 14.* Ventriculogram showing bizarre defect created by anomaly in the median fissure on surface of right parietal lobe.

*Case 14.* E.A. was a 49-year-old white female admitted on Nov. 8, 1948. She had an 18-year history of severe, left-sided headaches and Jacksonian epilepsy manifested primarily by twitching of the right side of the face. Six years after onset her fits became generalized and gradually increased in frequency and severity. Severe pain in the left side of the face had been treated elsewhere by alcohol blocks in the 2nd and 3rd divisions of the trigeminal nerve. Previous to admission her epilepsy had become uncontrolled and the headache constant and severe. On examination she was quite disoriented in all spheres; however, she had no other focal signs. Ventriculography on Nov. 17, 1948 revealed a right parietal parasagittal, space-taking lesion (Fig. 10). On Nov. 18, 1948 a midline parietal, frontal flap was turned down demonstrating a large arteriovenous anomaly of the medial portion of the parietal lobe. All of the large afferent vessels were ligated with silk and silver clips and coagulated. The patient expired on the 33rd postoperative day, never having reacted. Autopsy was refused.

*Case 15.* B.A. was a 44-year-old Mexican male admitted on Nov. 11, 1948 with

the history of having suffered a subarachnoid hemorrhage 2 months before. He continued to have residual severe, generalized headache, marked blurring of vision, photophobia, and was aphasic. On examination he presented a right homonymous hemianopia and aphasia without other focal signs. Routine x-rays showed increased vascularity over the left side of the skull. There was a pineal shift to the right of about 5 mm. An arteriogram demonstrated an anomally (Fig. 11). On Nov. 22,

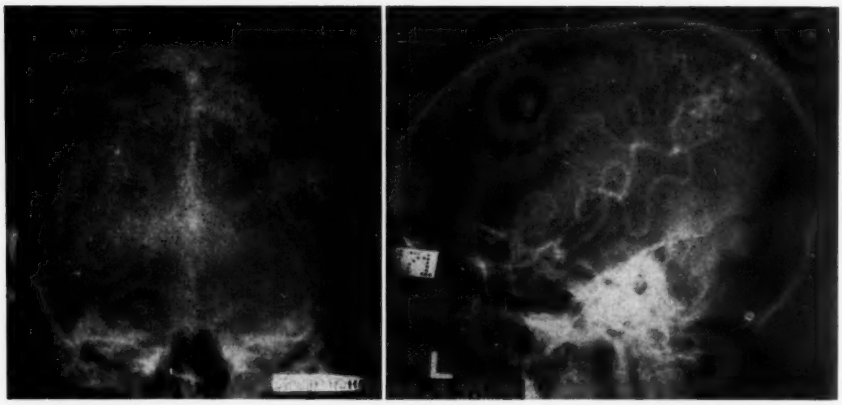

FIG. 11. *Case 15.* Frontal and lateral angiograms showing an occipital polar anomaly with afferent components arising from both the anterior and middle cerebral systems.

1948 a left parietal flap was turned down exposing a large arteriovenous anomaly. All of the visible afferent components were ligated and block excision of the lesion was carried out. He has been seen many times since. His aphasia has cleared completely, according to Spanish interpreters. His only residual is a persistent right homonymous hemianopic field defect.

*Case 16.* G.W. was a 40-year-old white female admitted on July 19, 1949. She had had headaches for several years, and during the past year they had been increasing in duration, frequency and severity. In the last 6 months she had had 3 subarachnoid hemorrhages with no residuals. An arteriogram (Fig. 12) demonstrated a callosal defect similar to that encountered in Case 12 (Fig. 8). On Aug 2, 1949, a 6-hole flap was elevated from the vertex and the major afferent components from the anterior cerebral vessels were ligated. With the ligation of the last large vessel there was a marked decrease in the volume of the lesion, which was then further thrombosed and shrunk down by the electrosurgical unit. She is without signs or symptoms to date.

*Case 17.* P.T. was a 21-year-old white female admitted on July 28, 1949. She had been seen frequently as an outpatient for 18 months. She had right Jacksonian fits when first seen in October, 1948, which became increasingly more difficult to control with medication. These had come on following onset of severe headaches in January 1946. There were no focal neurological signs. A pneumoencephalogram revealed a bizarre, space-occupying, midline, frontoparietal lesion (Fig. 13). An arteriogram

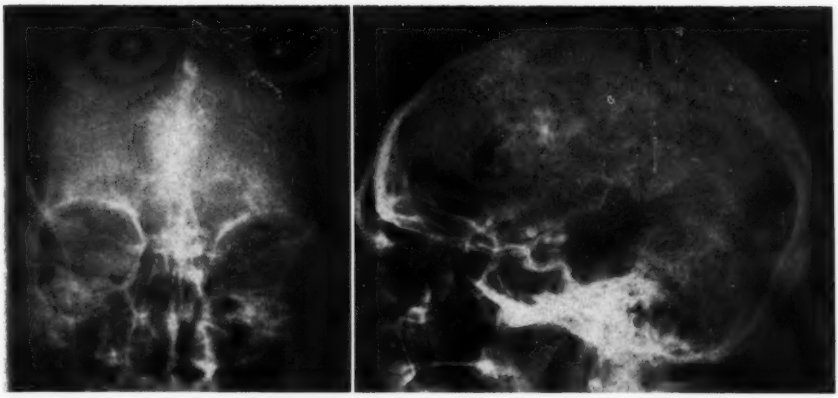

FIG. 12. *Case 16.* Frontal and lateral angiograms showing frontal callosal anomaly arising from both anterior cerebral systems with efferent components to the vein of Galen and the inferior sagittal sinus.

hen demonstrated the arteriovenous anomaly (Fig. 14). On Aug. 9, 1949 a bifrontal flap was elevated exposing a large angioma involving the posterior portion of the left frontal lobe. One or two large abnormal vessels coursing over the superior and medial surfaces of the right hemisphere were ligated with silver clips and thrombosed with the electrosurgical unit. The main lesion involving the left posterior frontal lobe was attacked by individual ligation of all the demonstrable afferent components. Total removal was begun by rolling the lesion toward the midline with

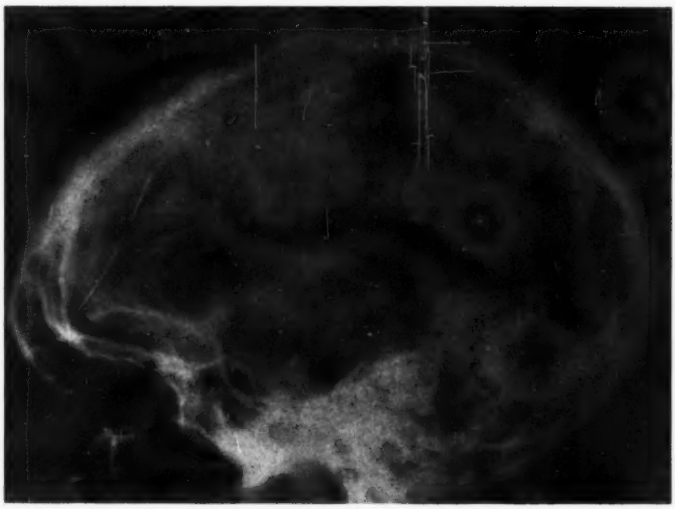

FIG. 13. *Case 17.* Lateral pneumogram showing bizarre filling defects (anomalous vessels) and increased subarachnoid cortical markings suggesting atrophy.

FIG. 14. *Case 17.* Left lateral angiogram showing large posterior frontal anomaly (indistinct due to rapidity of flow in channels so large) with afferent contribution from anterior and middle cerebral systems. Drainage was entirely through the superior longitudinal sinus.

its connections to the superior sagittal sinus acting as a hinge. Extremely brisk bleeding was encountered during this procedure and for this reason, with the lesion more than half isolated, the wound was packed and closed. On Aug. 18, 1949 the procedure was completed. Bleeding was controlled by silver clips, muscle grafts, and electrothrombosis. In her immediate postoperative period she had profound

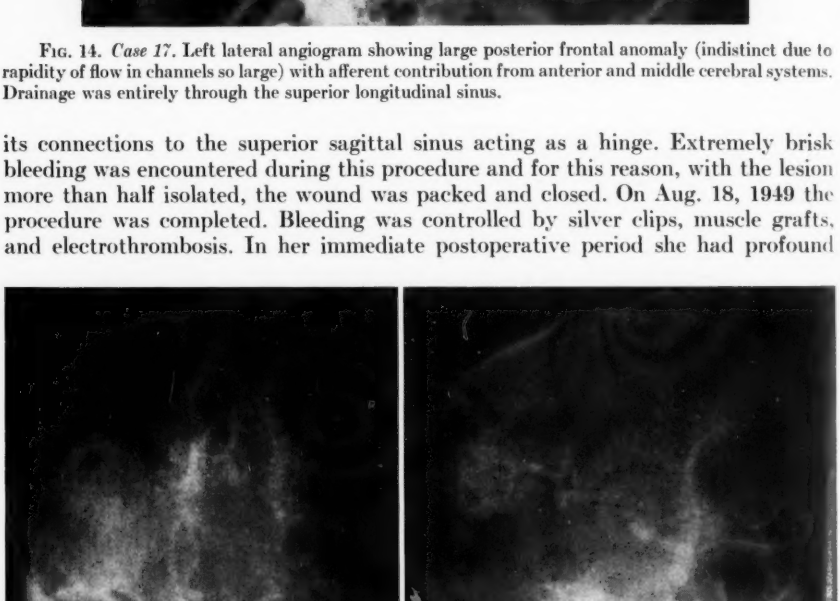

FIG. 15. *Case 18.* Frontal and oblique angiograms showing large left occipital polar anomaly with major feeders arising from both the anterior and middle cerebral system.

hemiplegia and was totally aphasic. During the 1st month her aphasia and hemiplegia disappeared except for a foot drop on the right. Her fits were easily controlled on medication and she returned to work as a secretary. During the last 6 months to date her foot drop has become minimal.

*Case 18.* J.D. was 52-year-old Mexican male admitted on Jan. 11, 1950 with the complaint of headache which was diminishing. In October, 1949 he had had a buzzing in his left ear. On Oct. 31, 1949, he had sudden onset of coma persisting for 15 to 20 days. CSF had been bloody and there was a bruit. Upon awakening he had a complete 6th nerve palsy on the left and severe headache. The bruit was less distinguishable. Upon admission no bruit could be heard. There were no objective findings except suggestive tortuosity of retinal vessels. B.P. was 200/120 and x-ray of the chest revealed bilateral apical tuberculosis of questionable activity. An angiogram demonstrated a large left occipital parietal angioma (Fig. 15). In view of the patient's age, recent onset and paucity of symptoms, questionably active tuberculosis and hypertension, expectant treatment was felt advisable and the patient was discharged. He returned Mar. 13, 1950, asymptomatic and without further objective signs. He will be followed at 6-month intervals.

## TREATMENT

Treatment of these lesions is expectant and surgical.

Expectant management is well illustrated by Cases 12 and 18. In each the lesion was demonstrated. However, since objective findings of progressive neurologic deficit, uncontrolled epilepsy, intolerable pain and recurrent bleeding were not present, active surgical attack had and has been deferred.

Subarachnoid bleeding does not appear to have been common in other cases in the literature with the exception of those reported by Wechsler and Gross.[8] Most of our cases have had this complication although in no instance was the effect as devastating as that from the subarachnoid hemorrhage accompanying rupture of an aneurysm. Intracerebral bleeding, however, is crippling. Eleven patients have been subjected to one or more experiences with subarachnoid or intracerebral hemorrhage. They all had headaches of increasing frequency and severity and they all had fits which increased in frequency and severity in spite of adequate medical measures for their control. With the progressive development of any or all of these undesirable signs and symptoms, we believe that surgical treatment is mandatory if irreversible brain damage is to be prevented.

We do not believe that irradiation has a place in the treatment of these lesions since, in order to bring about change in the abnormal vessels, irradiation of sufficient degree to destroy the normal blood supply as well as to bring about changes within brain tissue would be necessary.

The location of the angioma as well as the location of its primary afferent components from the arterial side of the circulation as demonstrated in the arteriogram determines the method of attack.

Basal avertin and intratracheal nitrous oxide, oxygen, and ether is the anesthesia of choice in our experience.

Exposure is facilitated by drainage of cerebrospinal fluid through a lumbar puncture needle and tubing inserted just before positioning on the table. With complete drainage at the time of dural opening, marked increase in brain mobility is obtained.

The polar lesions may be easily isolated, particularly in the frontal and temporal poles, since their major feeders from either the anterior or middle cerebral arteries are easily approached. Following ligature of the main feeder vessels, the efferent elements communicating with the major dural sinuses may be ligated and the lesion dissected completely free by gentle blunt teasing.

Those lesions situated within the midpolar portions of the brain and penetrating deep within the parenchyma present a different problem. Usually their main afferent components arise from the middle cerebral artery and these structures can therefore be approached and ligated by arachnoidal dissection of this vessel, utilizing the pituitary approach to the carotid exposing the middle cerebral artery at its source. If situated within the midportion of the dominant hemisphere or deep in the basal ganglia, no further attempt at removal can be made with discretion other than to coagulate the accessible portions of the angioma with low voltage *cutting* current thus inducing widespread thrombosis.

The low voltage *cutting* current has a damped spark which is not hot enough to tear or liquefy the vessel walls or cause them to stick and tear when the instrument is removed. The abnormal vessels can then be smoothly and gently shrunken and totally thrombosed by stroking with the ball tip. Deeply situated lesions can be approached, their afferent components ligated, and the accessible portion of the anomaly thrombosed in this manner.

Lesions occurring on the surface away from the motor strip can be dissected free by careful teasing and individual step-by-step ligation of the afferent arterial components.

It is important to remember that ligation of any but afferent elements to the anomaly in the initial steps of the dissection will result in serious hemorrhage which may almost certainly result in brain damage if not in rapid exsanguination of the patient.

It has been our experience that these lesions can be most effectively dealt with by finger compression technique. If massive hemorrhage occurs the lesion can be milked dry by gentle finger compression and gradually rolled out of the brain bed as rapid ligation of feeder vessels with silver clips is utilized, the efferent venous components being occluded last. In some instances it may be necessary to do the removal in two stages, particularly if hemorrhage has been brisk and voluminous, as in Case 17, in which it was necessary to control the bleeding with packs which were removed on the 9th day and 2nd-stage total excision was done.

Simple ligation of the carotid artery in our experience is worthless since the collateral circulation present in these anomalous vascular structure

is excessive. Case 17 had total ligation of the common, internal, and external carotid vessels with no abatement of the hemorrhage during the 1st stage of the procedure. Common carotid ligation alone can be of no value.

Emphasis upon the use of transfusions of whole blood is important. It is not enough in attacking such formidable lesions as these to have blood available in a bank or in the operating room to be utilized only when signs for its need are too obvious. The primary principle of treatment for shock induced by blood loss is anticipatory prevention. Therefore, transfusion should be instituted before the skull is opened and the rate of administration determined by minute-to-minute evaluation of changes in the vital signs dependent upon peripheral vascular stability.

## POSTOPERATIVE MORBIDITY AND MORTALITY

All of these patients operated upon demonstrated an associated postoperative neurologic deficit peculiar to the locus of the lesion. However, with the exception of Case 11 and Case 13 these signs cleared rapidly within 10 days to 6 weeks following operation. It is possible that this deficit represents not so much a sequel to trauma to the brain as it does the result of residual low-grade thrombosis on the venous side of the abnormal circulation with concomitant edema which gradually subsides as resolution of thrombosis occurs.

None of the survivors who could be followed was made worse by operation. Those who had headaches are now free; those who had uncontrolled fits now have none or a negligible number and they are more readily controlled on the usual dosages of anticonvulsant medication. Of more real danger to permanent brain crippling than operation itself is the risk of intracerebral hemorrhage, which had occurred in Cases 11 and 13 preoperatively.

There were 2 deaths in this series. That of Case 8 we felt was avoidable and induced by injudicious use of parenteral fluids in the acute postoperative state. Removal of such a large reservoir and shunt from the circulatory system and the temporary low-grade thrombosis resulting on the venous side of the system probably account for the ease of production of cerebral edema. Case 14 had been moribund for several days preceding admission. Clinically it was felt that death was due to patchy atelectasis with pneumonia and renal failure. Since autopsy was refused it was impossible to determine the exact role of the brain lesion in her demise.

## SUMMARY

Experiences with the management of 18 cases of arteriovenous anomaly of the brain have been presented. It is felt that direct surgical attack is the treatment of choice when symptomatology becomes progressive and unmanageable.

The technique of attack is determined by the situation of the lesion with reference to depth, accessibility and its major arterial supply—points demonstrated by the angiogram.

## REFERENCES

1. Cushing, H., and Bailey, P. Tumors arising from the blood-vessels of the brain. Angiomatous malformations and hemangioblastomas. *Springfield, Ill.: Charles C Thomas*, 1928, x, 219 pp.
2. Dandy, W. E. Venous abnormalities and angiomas of the brain. *Arch. Surg., Chicago*, 1928, *17:* 715–793.
3. Norlén, G. Arteriovenous aneurysms of the brain. Report of ten cases of total removal of the lesion. *J. Neurosurg.*, 1949, *6:* 475–494.
4. Olivecrona, H., and Riives, J. Arteriovenous aneurysms of the brain. Their diagnosis and treatment. *Arch. Neurol. Psychiat., Chicago*, 1948, *59:* 567–602.
5. Pilcher, C. Angiomatous malformations of the brain. Successful extirpation in three cases. *Ann. Surg.*, 1946, *123:* 766–784.
6. Ray, B. S. Cerebral arteriovenous aneurysms. *Surg. Gynec. Obstet.*, 1941, *73:* 615–648.
7. Trupp, M., and Sachs, E. Vascular tumors of the brain and spinal cord and their treatment. *J. Neurosurg.*, 1948, *5:* 354–371.
8. Wechsler, I. S., and Gross, S. W. Cerebral arteriography in subarachnoid hemorrhage. *J. Amer. med. Ass.*, 1948, *136:* 517–521.

# SPECIFIC TREATMENT OF INTRACRANIAL ANEURYSMS

## EXPERIENCES WITH 143 SURGICALLY TREATED PATIENTS*

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CONSIDERABLE progress has been made in the past ten years in the surgical treatment of intracranial aneurysms. It has been possible to reach certain conclusions from the results obtained following the various surgical procedures that were instituted in 143 patients with verified intracranial aneurysms. These results, even though encouraging, indicate that much has to be learned about the management of intracranial aneurysms.

In the analysis of these 143 cases, one is impressed with the fact that intracranial aneurysms develop at favorite sites. Valuable information is thus gained from actual experience with aneurysms at specific locations and under specific conditions. Sufficient numbers of patients have been treated surgically to justify the recording of impressions gained from the procedures used.

Neurosurgeons who have had surgical experience with intracranial aneurysms realize the dangers and pitfalls that become obvious at the time of operation only after it is too late to avoid tragic results. It is not my purpose to discourage but rather to encourage surgical treatment, not only to save these patients' lives but to safeguard their usefulness while attempting to effect that cure. The actual excision or trapping of an intracranial aneurysm is technically not difficult. If in the execution of the excision or trapping, however, a patient is hopelessly and permanently crippled or his usefulness has been permanently damaged, one might wish that he had taken a completely conservative course rather than carry out a surgical procedure. At the present time there is no technic that will insure complete safety in carrying out surgical procedures which may be instituted in intracranial aneurysms. There are, however, indications and contraindications which are of the utmost importance for specific types of surgical procedures.

Two courses may be followed in the treatment of intracranial aneurysms, either conservative or surgical. Conservative treatment is justifiable only in a few instances, such as in bilateral multiple intracranial aneurysms (Fig. 1), arteriosclerotic saccular aneurysms with minimal symptoms, arteriosclerotic aneurysmal dilatations that have produced no serious local symptoms, and in cases in which inadequate collateral circulation prevents either direct or indirect surgical attack.

* Presented at the meeting of the Harvey Cushing Society, Colorado Springs, Colorado, April 16, 1950.

The surgical treatment of intracranial aneurysms cannot be instituted intelligently without knowing the exact site of the aneurysm. The surgeon must know the tolerance of each cerebral hemisphere to reduction in blood supply. He must know whether the aneurysms are solitary, multiple or bilateral. He should also know the risk involved in the non-surgical intervention versus surgical attack.

The proper treatment of intracranial aneurysms cannot be decided

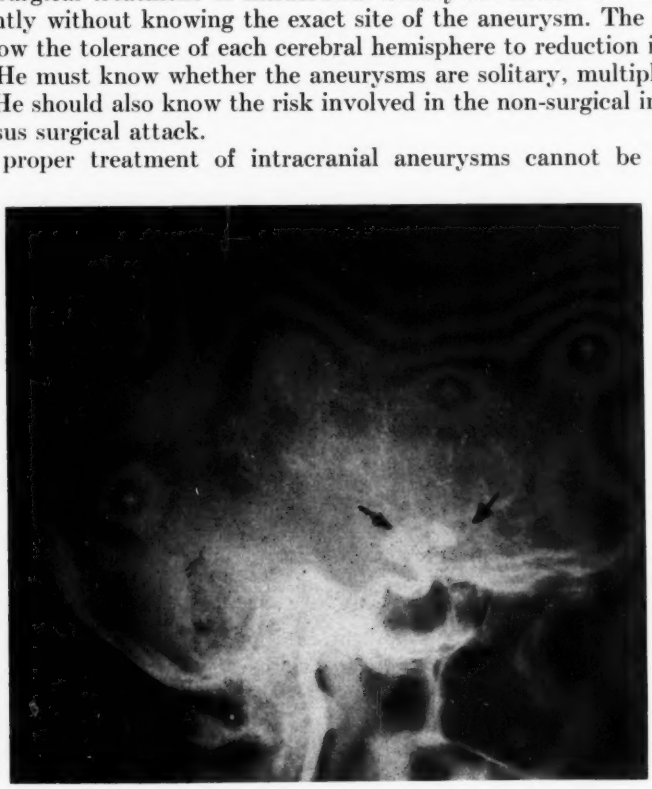

FIG. 1. Angiogram demonstrating multiple unilateral aneurysms.

upon until adequate studies have been made. The diagnosis cannot be made with certainty until the presence of an intracranial aneurysm is verified by adequate arteriography. Even though spontaneous subarachnoid hemorrhage is a definite indication of the presence of a leaking or ruptured intracranial aneurysm, angiomas, blood-vessel malformations, mycotic emboli, blood dyscrasias, and fragility of blood vessels as found in hypertension or brain tumors may actually be the cause of the hemorrhage rather than the suspected aneurysm. Therefore, statistics as to the results of treatment of intracranial aneurysms must be based on actual demonstration of the lesion rather than on the mere presence of subarachnoid bleeding.

There should be no hesitancy in carrying out arteriograms at any stage of the subarachnoid bleeding. I am convinced, however, that arteriography should not be carried out under local anesthesia unless the superior cervical sympathetic ganglion and carotid sinus have been thoroughly anesthetized

with procaine before the contrast medium is introduced. The peripheral cerebral arteries are at times in spasm from trauma to the arterial wall by the rupture of the aneurysm and the resulting perivascular extravasation of blood. The added insult caused by the injection of contrast media may induce further spasm, thus not only preventing adequate visualization but also possibly producing prolonged arteriospasm. The course of treatment that should be followed in each patient who is to be treated for an intracranial aneurysm can usually be decided from the arteriograms.

A few patients can be saved by surgical intervention at the initial attack of a subarachnoid hemorrhage if seen sufficiently early. It is, however, the patient who has had a recent (within 1 week) subarachnoid hemorrhage who should receive the most careful attention and study. There can be no question but that further bleeding develops within the 2nd and 3rd weeks of the initial rupture in a definite number of patients who survive the initial subarachnoid hemorrhage. It seems to be good judgment, therefore, to initiate surgical treatment in these patients, granting that a certain number may not have a subsequent hemorrhage for many months or years.

## TREATMENT

*Conservative Treatment.* As already indicated, conservative treatment is not justifiable except in specific instances. After adequate studies have indicated that surgical treatment is almost certain to be followed by catastrophe, one naturally should forego surgery.

*Indirect Surgical Attack.* The indirect surgical attack consists of ligation of a large artery or arteries in the neck, usually the internal carotid artery, in an attempt to lower the intra-aneurysmal arterial pressure. The indirect attack is the procedure of choice in the majority of patients in whom the aneurysm is confined to the bifurcations of the larger arteries in the circle of Willis (Fig. 2). The indirect attack should not be utilized in aneurysms favorable for excision (Fig. 3) or in instances in which it could be of little or no value, as might be the case when the aneurysms are well away from the circle of Willis (Figs. 4, 5, and 6).

Several methods of ligation have been devised, no doubt because occlusion of the carotid system in the neck may be followed by serious sequelae. At times partial occlusion may be necessary in patients who do not tolerate complete interruption of the internal carotid artery. Partial occlusion of the carotid system may be obtained by the use of fascial strips, cellophane wrapping, special bands or partial interruption by silk ligatures. If partial interruption is necessary, I prefer to make use of the normal structures, that is ligate the common carotid artery which reduces the blood flow approximately one half or, if the ipsilateral cerebral hemisphere tolerates a greater reduction in blood flow, ligate the common carotid artery and the external carotid artery above the external maxillary artery. This allows several branches of the external carotid artery to feed the internal carotid artery.

Ligation of the internal carotid seems to be a safer procedure than

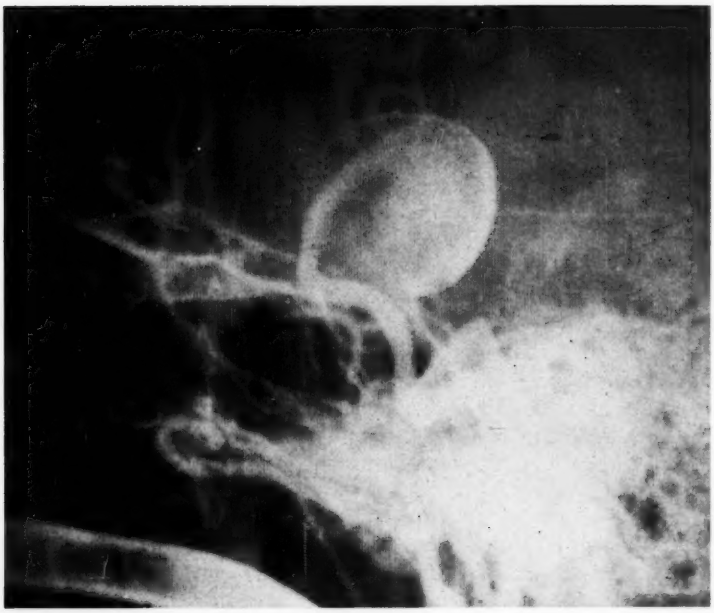

FIG. 2. Large globular aneurysm involving bifurcations of the larger arteries of the circle of Willis.

ligation of the common carotid artery, providing the collateral cerebral circulation is adequate. The reason for this is perhaps the diameter and thickness of the arterial wall and also the fact that atheromatous plaques are found more frequently in the common carotid artery than in the internal or external carotid arteries. Great caution must, therefore, be exercised in avoiding acute constriction of the artery at the site of the calcified plaque, fracture of which will cause a rupture of the intima, resulting in the local formation of a thrombus. If the calcium

FIG. 3. Angiogram demonstrating saccular aneurysm favorable for excision.

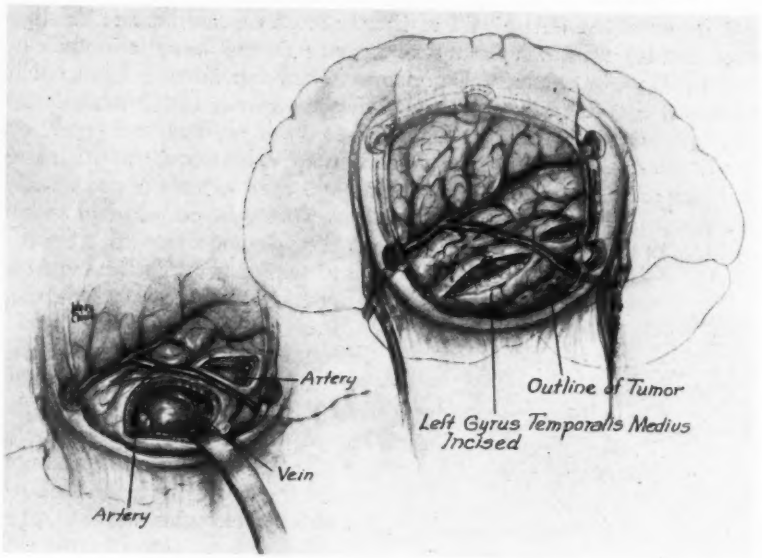


FIG. 4. Exposure of a large intracerebral aneurysm involving a temporal branch of the middle cerebral artery.

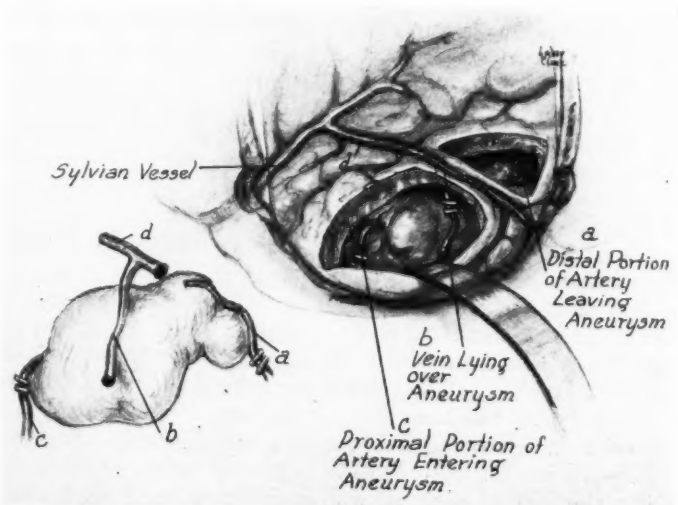


FIG. 5. Uncapping of large aneurysm. *Inset*, Sketch of aneurysm after removal (see Fig. 6).

deposit involves the entire wall of the common carotid artery, the ligature may weaken the wall to such an extent that a rupture may take place at the time of ligation, or a local false aneurysm develop later. I favor occlusion of the vessel chosen for ligation by taking advantage of the normal carotid sheath, imbricating it for a distance of 3 to 4 cm. with several layers of fine black silk until the lumen is completely closed, reinforcing this with a single larger black silk ligature on the cephalad and caudad ends of the vessel that has been completely occluded by the constricting layers of black silk. The silk sutures are tied down loosely so that they do not traumatize the intima but will prevent the lumen from reopening at a later date by stretching of the adventitial layer. Considerable care must be used in the exposure of the artery so that the sheath is kept intact. Also, trauma of the intima with a suture needle would obviate any advantage this method might offer. This technic has been described elsewhere.

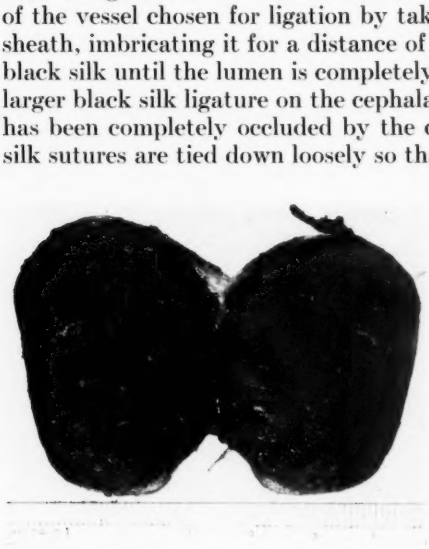

FIG 6. Actual surgical specimen (See Fig. 5).

I have hesitated to divide the internal carotid artery deliberately at the time of ligation as advocated by Rogers[1] and others. In one instance contralateral weakness of the extremities did not develop until 2 hours after ligation. Immediate return of function took place upon removal of the ligature. It is logical, however, to assume that dislodgment of an embolus is more likely to occur with occlusion in continuity than with interruption of the continuity because of the tug on the artery at the site of the ligature during each heart beat. It is possible that the percentage of serious consequences may prove to be less in patients in whom the continuity of the arterial wall has been interrupted. At the time of ligation, it is important that the carotid sinus is well anesthetized and the superior cervical ganglion perfused with procaine.

It has been my practice in the past either to divide the sympathetic trunk immediately beneath the superior cervical ganglion or to crush it in patients who had demonstrated irritability of the carotid sinus previous to ligation. This was also instituted in all patients with large subclinoidal aneurysms which had already caused ocular palsies from local pressure. More recently, however, to obviate a temporary or permanent Horner's syndrome, a polyethylene tube has been sutured into the sheath of the superior cervical ganglion and a slow concentrated procaine drip allowed to perfuse the ganglion for several days following operation (Fig. 7). This accomplishes the desired effect as well as crushing or dividing the sympa

thetic trunk. Besides, it has the added advantage of preventing any prolonged undesirable effects of sympathetic interruption.

The precautions that should be used during and after ligation of the internal carotid artery are important. It is necessary to maintain a normal blood pressure and proper oxygenation, to use either local or regional anesthesia so that the patient's state of consciousness and reactions may be observed, to avoid trauma to the intima of the artery, to refrain from placement of a ligature over a sclerotic plaque, and to interrupt the carotid sinus and sympathetic trunk beneath the superior cervical ganglion. Interruption of the carotid sinus and sympathetic trunk was accomplished more recently by the use of polyethylene tubing and constant perfusion of the superior cervical ganglion with procaine for 2 to 3 days following ligation. Adequate oxygenation should be continued for at least 24 hours following operation. Anticoagulation should be instituted 4 hours following ligation except in patients who have had a recent subarachnoid hemorrhage (within 2 weeks). Manipulation of the site of operation should be avoided during dressings for fear of dislodging a possible embolus.

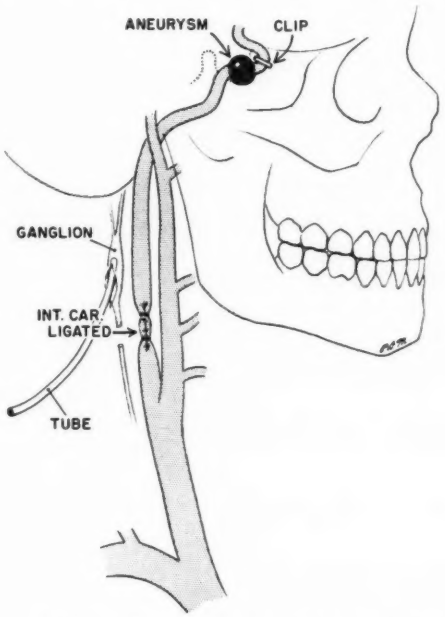


FIG. 7. Trapping of an aneurysm of the internal carotid artery and method of interrupting sympathetic impulses with procaine by means of polyethylene tubing inserted into the sheath of the superior cervical ganglion for a period of several days following ligation. Division of sympathetic trunk is also shown, which may be done in certain instances.

There were 101 patients subjected to ligation of a large artery in the neck.

## THREE DEATHS FOLLOWING LIGATION

Three deaths followed ligation. One patient, a 40-year-old woman with a history of hypertension, was seen 14 hours following the initial hemorrhage. Bleeding continued and weakness of the left side developed. Angiograms demonstrated an aneurysm. Ligation of the right internal carotid artery was followed by death 10 hours later. The 2nd patient, a 65-year-old woman, was seen 18 hours after the rupture of an aneurysm which was visualized by arteriography; it involved the bifurcation of the left internal and middle

cerebral arteries. Because of progressive signs, ligation of the internal carotid artery was performed. Four hours later a sudden left-sided or ipsilateral hemiplegia took place. Autopsy revealed a saccular aneurysm of the right middle cerebral artery which had ruptured. It was this patient who demonstrated so vividly that it is essential to visualize both carotid systems before a surgical procedure is instituted. The aneurysm on the side that was ligated was intact with the exception of a small thrombus at the site of the recent rupture. The 3rd case demonstrates that anticoagulation is not without danger and should be avoided in patients who have recently had a subarachnoid hemorrhage. A 46-year-old woman, with a vestigial aneurysm located at the bifurcation of the internal carotid and middle cerebral arteries on the right side, was subjected to ligation of the right internal carotid artery. Anticoagulation was instituted 4 hours after ligation. Unfortunately, the bleeding time was not adequately controlled and fresh, sudden bleeding occurred from the aneurysm, resulting in death.

These deaths emphasize the importance of adequate arteriography of both carotid systems before surgery is instituted, and that caution should be exercised in the use of anticoagulation agents. These agents should be reserved for patients, subjected to ligations, who have large aneurysms causing local symptoms but no history of rupture into the subarachnoid spaces, or for patients in whom the aneurysm has ruptured into the cavernous sinus.

## EIGHT SUBSEQUENT DEATHS FOLLOWING LIGATION

*Case 1.* A 66-year-old woman, with hypertension, had sudden blindness and pulsating exophthalmos with complete ophthalmoplegia of the left eye 24 days previous to admission. She complained of severe left-sided headaches. Digital compression of either internal carotid artery in the neck caused untoward symptoms. Following anesthetization of the left superior cervical ganglion with procaine, digital compression was well tolerated. Arteriograms demonstrated rupture of an intracranial aneurysm into the left cavernous sinus. Partial ligation with cellophane and division of the sympathetic trunk on the left side were followed by a right pulsating exophthalmos and right hemiplegia 22 days later, and sudden death from pulmonary embolus 24 days after ligation. The circle of Willis as found at autopsy demonstrated bilateral atresia of the posterior communicating arteries and bilateral saccular aneurysms of the internal carotid arteries, with rupture into the cavernous sinus on the left and more recently on the right.

*Case 2.* A man, 55 years old, had hypertension (200/120) and severe left-sided headaches. Bilateral arteriography was done. Angiograms demonstrated a small saccular aneurysm at the bifurcation of the left internal carotid and middle cerebral arteries. Ligation of the internal carotid artery with section of the sympathetic trunk was performed; no postoperative complications occurred. An excellent result was obtained for 1½ years. The patient died suddenly from hypertensive cerebral hemorrhage on the right side, opposite the site of the aneurysm. Autopsy was not performed.

*Case 3.* A woman, 36 years old, had pulsating exophthalmos, generalized con-

vulsions and periods of mental depression. Angiograms demonstrated a large aneurysm with venous communications (Fig. 8). The left internal carotid artery was ligated; no complications occurred. Subsequent roentgenograms demonstrated partial calcification in the wall of the aneurysm. She was well for 9 years and then committed suicide.

*Case 4.* A woman, aged 67 years, had sudden left-sided headaches and ophthalmoplegia of 7 weeks' duration. Angiograms demonstrated an aneurysm at the bifur-

FIG. 8. Angiogram demonstrating large aneurysm with venous communications.

cation of the internal carotid and middle cerebral arteries. Ligation of the common carotid and external carotid arteries distal to the external maxillary artery and section of the sympathetic trunk beneath the superior cervical ganglion were well tolerated. An excellent result was obtained for 3 years. The patient died of cardiac disease.

*Case 5.* A woman, aged 48 years, had right-sided severe headaches, severe trigeminal pain of the 1st and 2nd divisions, poor vision in the right eye and nausea and vomiting of 2 days' duration. Examination revealed optic atrophy on the right and bloody CSF. Right-sided angiograms only were made which demonstrated a large subclinoidal aneurysm. The common carotid and external carotid arteries were ligated above the external maxillary artery. Severe neuralgia persisted following ligation. Interruption of the continuity of the internal carotid artery and the sympathetic trunk was carried out, with complete relief 2 weeks later. She was well for 4 years and then blindness of the left eye developed due to a large aneurysm of the

left internal carotid artery. She died 5 years following the initial ligation with blindness of the left eye and partial blindness of the right eye (ligated side).

*Case 6.* A woman, aged 30 years, had periods of hallucinations for several years followed by sudden onset of right-sided headaches and subarachnoid hemorrhage. Angiograms demonstrated an aneurysm at the bifurcation of the left middle cerebral and internal carotid arteries. A right angiogram was not made. Ligation of the left internal carotid artery was well tolerated. Death occurred 18 months later from subarachnoid hemorrhage, presumably from rupture of the aneurysm. Autopsy was not performed.

*Case 7.* A man, aged 59 years, had right ophthalmoplegia of 2 months' duration and severe right-sided headaches. Angiograms demonstrated a vestigial aneurysm of the right internal carotid artery near its bifurcation. The common carotid artery, which was sclerotic, was ligated. There were no immediate complications. Four weeks later a large mass developed in the neck at the site of the ligation. Sudden rupture of a false aneurysm caused by ligation of the sclerotic carotid artery, resulted in rapid death.

*Case 8.* A woman, aged 26 years, had sudden severe headaches and subarachnoid hemorrhage. Angiograms demonstrated an aneurysm at the bifurcation of the left middle and internal carotid arteries. The left common carotid artery was ligated, with no resulting complications. She was well for 1½ years and then died suddenly, presumably from a ruptured aneurysm.

These subsequent deaths following dismissal from the hospital emphasize the importance of bilateral arteriography to rule out the presence of bilateral aneurysms. Also, ligations over an arteriosclerotic plaque should be discouraged. In only 1 instance was the ligation directly responsible for death. In 2 instances ligation was inadequate to prevent subsequent death, presumably from rupture of the aneurysm.

## HEMIPLEGIA FOLLOWING LIGATION

*Case 9.* A woman, aged 32 years, had headaches, diplopia and convulsions. There was a history of several subarachnoid hemorrhages. Arteriograms demonstrated multiple unilateral aneurysms on the left side. Ligation of the left internal carotid artery was well tolerated for 48 hours, followed by a sudden complete right-sided hemiplegia and aphasia. The speech returned within several hours but a permanent spastic gait resulted. Five years after ligation, the patient is able to carry out household activities with a brace on the right foot.

*Case 10.* A woman, aged 39 years, had periodic generalized headaches. She had had three arachnoid hemorrhages. Arteriograms demonstrated a large saccular aneurysm at the bifurcation of the left middle and internal carotid arteries. Ligation of the internal carotid artery on the left side was followed by complete hemiplegia in 8 hours. Speech returned in 3 weeks. Hemiplegia persisted to be incapacitating for 3 years. Gradual improvement has taken place in the past 2 years; she is able to do all her housework—cook, clean house, sew—and walks without support.

*Case 11.* A woman, aged 56 years, gave a history of headaches and subarachnoid hemorrhage. Arteriograms demonstrated an aneurysm at the bifurcation of the middle and internal carotid arteries. Ligation was followed by complete hemiplegia in 12 hours. Incomplete recovery of the use of the extremities resulted. Five years later she was unable to carry out her normal household activities.

*Case 12.* A woman, aged 27 years, had an arteriovenous aneurysm on the left, rupture having taken place into the petrosal and basilar sinuses. Ligation was carried out, with no untoward signs for 8 days. Palpation of the operative site was followed by sudden hemiplegia. Complete recovery took place several days later.

*Case 13.* A man, aged 49 years, gave a history of subarachnoid hemorrhage. Arteriograms demonstrated an aneurysm at the bifurcation of the left middle cerebral and internal carotid arteries. The left internal carotid artery was ligated and sudden hemiplegia occurred 6 days later. Speech returned promptly, but there was partial hemiplegia for 1 year.

*Case 14.* A man, aged 27 years, had subarachnoid hemorrhage and persistent headaches. Arteriograms demonstrated aneurysms of the right anterior cerebral artery and occlusion of the left anterior cerebral artery. Ligation of the left internal carotid artery was followed by a sudden left-sided hemiplegia in 36 hours. Immediate recovery followed procaine block of the superior cervical ganglion.

*Case 15.* A man, aged 49 years, had had a recent subarachnoid hemorrhage. An arteriogram demonstrated an aneurysm of the left internal carotid artery at its bifurcation with the middle cerebral artery. Sudden right-sided hemiplegia and aphasia developed 6 days after ligation. The aphasia began to improve after several hours, and slight movement started in the extremities following infiltration of procaine into the superior cervical ganglion. Partial hemiplegia prevents the carrying out of his usual activities up to the present date.

*Case 16.* A woman, 67 years of age, had subarachnoid hemorrhage, right ophthalmoplegia and hypertension. Arteriograms demonstrated a large saccular aneurysm at the bifurcation of the internal carotid artery. Ligation of the right internal carotid artery was followed by left hemiplegia in 2 hours. Release of the ligatures resulted in dramatic, immediate return of the function of the left extremities. Seven days later the right internal carotid artery was ligated, with no ill effects. The patient is still alive 7 years after ligation, with no complaints.

## RELIEF OF SYMPTOMS FOLLOWING LIGATION

In 3 patients the pain in the distribution of the 1st and 2nd divisions of the trigeminal nerve persisted following ligation. Two of these patients were completely relieved by division of the internal carotid artery, which had previously been ligated, and section of the sympathetic trunk immediately beneath the superior cervical ganglion. The 3rd patient was not relieved by this procedure and only after avulsion of the 1st and 2nd divisions of the trigeminal nerve was the pain relieved. It is possible that in certain of these patients sensory root avulsion may have to be instituted if the above minor procedures do not suffice to give relief.

## MENTAL SYMPTOMS FOLLOWING LIGATION OF THE INTERNAL CAROTID ARTERY

Three patients who were treated for intracranial aneurysms had definite hallucinations and periods of depression. These symptoms were present before ligation was carried out. In 1 patient it was necessary to perform a bilateral prefrontal lobotomy. At the time of the lobotomy a small aneurysm involving the posterior communicating artery was trapped between silver clips (Fig. 9), with complete rehabilitation of the patient. No mental changes were noted as a direct result of the ligation of the internal carotid artery. Profound neurologic changes may take place following spontaneous occlusion of the internal carotid artery. This may well be due to changes that have taken place in the arterial walls of the intracranial arteries as well as in the internal carotid artery. Also, the activating agent producing the thrombosis may still be present, causing frequent or persistent arterial spasms. Improvement of symptoms in some of the patients who have spontaneous occlusion of the internal carotid artery may be obtained by excision of a segment of the internal carotid artery in the neck, combined with removal of the superior cervical sympathetic ganglion.

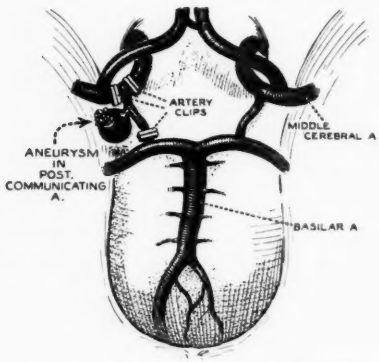


FIG. 9. Trapping of ruptured aneurysm attached to posterior communicating artery which allowed adequate collateral circulation for the middle cerebral artery through the anterior cerebral arteries.

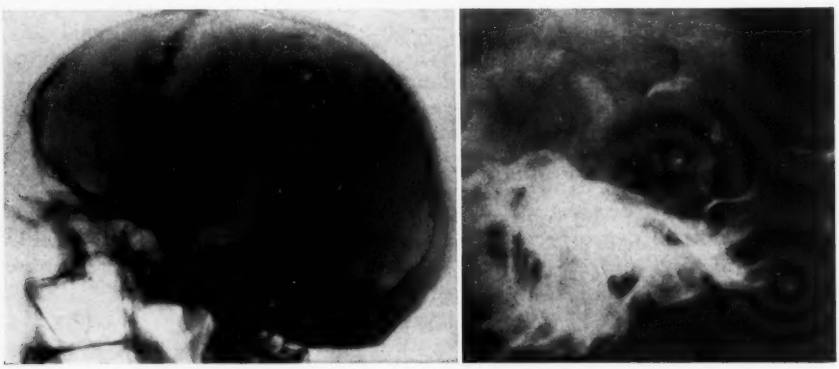

FIG. 10 (*left*). Calcification in the internal carotid artery 9 years following its ligation. (Reprinted by courtesy of *Radiology*, March 1949.)
FIG. 11 (*right*). Calcification of an intracranial aneurysm 5 years following ligation.

## ROENTGENOLOGIC CHANGE IN THE ANEURYSM FOLLOWING LIGATION

That healing after ligation does seem to occur in certain instances is indicated by calcification of the aneurysm, as demonstrated by Figs. 10 and 11.

That aneurysms enlarge without treatment is indicated by Fig. 12; arteriograms were taken at 6-month intervals.

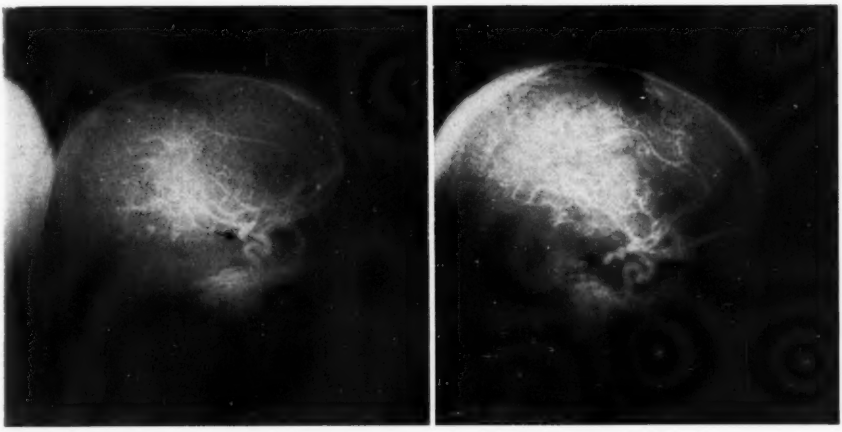

FIG. 12. Enlargement of a vestigial aneurysm in a 6-month period.

## DIRECT SURGICAL ATTACK

Direct intracranial surgical attack of intracranial aneurysms should be reserved for aneurysms that do not arise from the bifurcations of the larger arteries that make up the circle of Willis unless there is an adequate neck which allows occlusion at that point without interference with the main arterial trunks. This is rarely possible because of the attenuation of the walls of the artery at the neck of the aneurysm.

The direct intracranial attack may, in certain instances, be combined with the indirect attack, so-called trapping, in aneurysms that are proximal to the bifurcation of the internal carotid artery (Fig. 13) or in aneurysms that have ruptured into the cavernous sinus. Here again arteriograms must be made bilaterally; the arteriogram must satisfactorily demonstrate the technical possibility and feasibility either of trapping or excising the aneurysm. The arteriograms must be studied from the standpoint of arterial plaques that at times involve the neck of the aneurysm.

Serious consideration must be given to the risk involved to the life of the patient; also, his usefulness following operation must be weighed against his chances without surgical interference.

Intracranial aneurysms in a favorable site for a direct attack should be

FIG. 13. Arteriogram demonstrating parasellar aneurysm suitable for ligation of internal carotid artery in neck and intracranial occlusion distal to aneurysm.

trapped or excised. I firmly believe that excision should rarely be carried out except in instances in which the aneurysm is well away from the circle of Willis so that excision can be readily done. This is stated with a definite purpose in mind so that others may avoid the difficulties I have precipitated by actual excision of aneurysms, wishing to study them grossly and microscopically, as well as to demonstrate that such excision was possible. That this is not feasible routinely may be appreciated by the fact that at times only 1 or 2 mm. of artery is available for the application of a ligature or a silver clip. The excision of the aneurysm next to the clip or ligature removes much of its support to the clip and may permit the clip to slip off the attenuated wall of the neck, or in the manipulation of the aneurysm in preparation for excision, the fragile wall of the neck may rupture before the clip is applied.

## SPECIFIC SURGICAL ATTACK OF CRANIAL AND INTRACRANIAL ANEURYSMS

Aneurysms of the cranial portion of the carotid artery are extremely rare, no doubt because of the protection of the bony canal. If they do occur, the procedure of choice is ligation of the internal carotid artery in the neck and intracranial ligation of the internal carotid artery lateral to the optic nerve.

Aneurysms that involve the parasellar region should be trapped if sufficient length of the internal carotid artery distal to the aneurysm is available for the application of a silver clip or ligature. The question arises in these instances as to the sequence with which these procedures should be executed. I have ligated the internal carotid artery in the neck first in every instance except in 1 patient in whom the internal carotid artery was exposed and a ligature placed around it, the operative drapes having been prepared in such a manner that the craniotomy could be carried out at the same time. The intracranial portion of the internal carotid artery distal to the aneurysm was exposed and 2 silver clips applied. The internal carotid artery in the neck was simultaneously occluded by lifting the ligature which had previ-

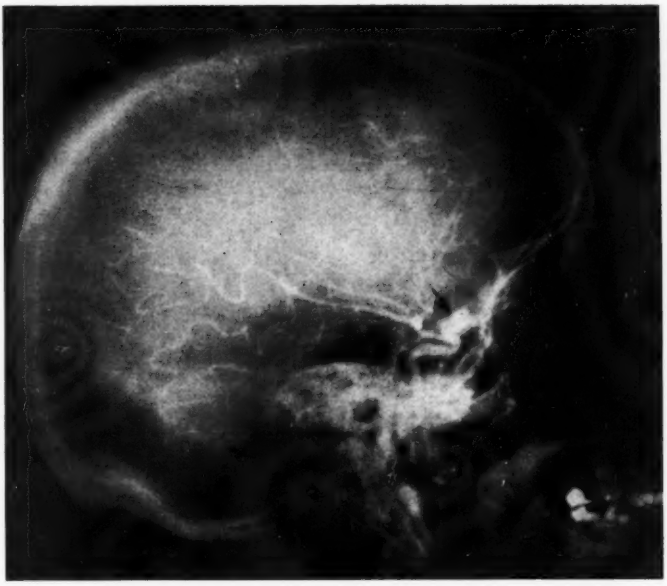

FIG. 14. Arteriogram demonstrating saccular aneurysm arising from the internal carotid artery suitable for excision or trapping intracranially.

ously been placed around it. The pulsation in the aneurysm ceased at the time the internal carotid artery was occluded by lifting the ligature in the neck. Upon release of the ligature in the cervical region, however, the pulsations became strong in the aneurysm and the silver clips previously applied to the intracranial portion of the internal carotid artery distal to the aneurysm could be seen to open slowly, and became displaced. The internal carotid artery was then ligated in the neck and the clips again applied. At this time there was no evidence that the clips would not permanently occlude the internal carotid artery intracranially. From a practical standpoint, therefore, it would seem preferable to ligate the internal carotid artery in the neck first, followed by occlusion of the distal intracranial portion of the internal carotid artery. If this is done immediately following the ligation it will prevent the chances of thrombosis or embolus. If immediate ischemia takes place, however, nothing can be done about it. At

FIG. 15. Operative sketch of aneurysm shown in Fig. 14.

the present time, therefore, I prefer first to ligate the internal carotid artery in the neck under local or regional anesthesia, to be followed by the intracranial ligation a few days later. Pedunculated aneurysms (see arrow) that arise from the internal carotid artery should be occluded (Figs. 14 and 15).

## ANEURYSMS AT THE BIFURCATION OF THE ANTERIOR PORTION OF THE CIRCLE OF WILLIS

Aneurysms at the bifurcation of the internal carotid artery, namely the anterior and middle cerebral arteries, usually point posteromedially; how-

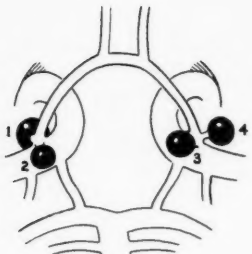

FIG. 16. (1) Anteromedial location at bifurcation, (2) aneurysm placed posteriorly, (3) aneurysm located posteromedially, with large neck, (4) aneurysm located anterolaterally with small neck.

FIG. 17. Aneurysm arising from bifurcation of internal and middle cerebral arteries unsuitable for direct attack.

ever, they may point posterolaterally, anterolaterally or anteromedially (Fig. 16). The majority of aneurysms located at the junctions are outpouchings rather than pedunculated. If pedunculated, the neck of the aneurysm is rarely long enough to allow its occlusion with a clip or ligature. I have attempted excision in 2 such instances. In an attempt to mobilize the aneurysm gently from the moderately dense arachnoidal adhesions that in many instances surround it, rupture took place, resulting in ligation of the major vessels in an effort to save the patient's life. One of the patients succumbed within 12 hours without regaining consciousness. The 2nd patient regained

consciousness and seemed to be in good condition with the exception of contralateral paralysis of the extremities, but died suddenly 36 hours following completion of the operation. Autopsy revealed a fresh intrapontine hemorrhage. The operative site showed no evidence of bleeding.

These experiences have greatly curtailed my enthusiasm for a deliberate attack on aneurysms arising from the bifurcations (Fig. 17), and at the present time ligation of the internal carotid artery is the procedure of choice. It is possible that occlusion of the internal carotid artery in the parasellar region may avoid the complications that have attended the ligations in the neck.

## VESTIGIAL ANEURYSMS

Vestigial aneurysms usually arise from the posterior portion of the internal carotid artery in the proximity of the posterior communicating or anterior carotid artery, but may arise from any portion of the internal carotid artery intracranially. These aneurysms develop in vestigial embryonic remnants and are commonly mistaken for aneurysms involving the posterior communicating artery.

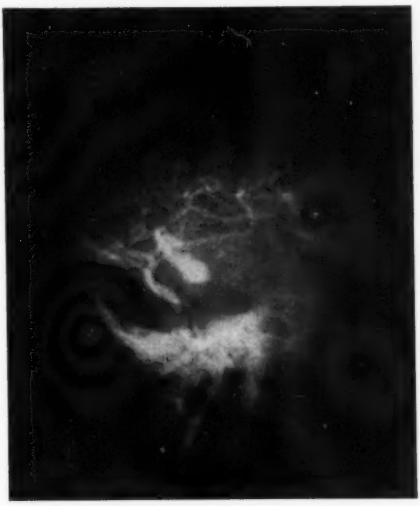

FIG. 18. Vestigial aneurysm suitable for excision.

The vestigial aneurysms form a favorable group for trapping or excision, as indicated by Figs. 18 and 19, *a* and *b*. It is important to study the arteriograms carefully, with particular attention directed to the neck of the aneurysm. The majority of these aneurysms are pedunculated. In several instances, however, arteriosclerotic plaques occurred in the neck; the latter are not visualized by the usual roentgenographic studies. Arteriograms may demonstrate a small defect, indicating such a condition (Fig. 19*b*). Placing a silver clip over an attenuated wall changed by an atheromatous plaque may well result in rupture of the vessel at the time of ligation and end in catastrophe. Ligation of the internal carotid artery is preferable in cases in which the neck of the aneurysm is involved with such a condition.

## ANEURYSMS OF THE ANTERIOR CEREBRAL ARTERY

The surgical treatment of fusiform and pedunculated aneurysms arising from the trunk of the anterior cerebral arteries presents no particular problem (Fig. 20, *a* and *b*). Excision or trapping of the left anterior cerebral artery

must be executed under ideal situations, great care being exercised to keep the blood pressure at a normal level and to maintain proper oxygenation during and after the operation.

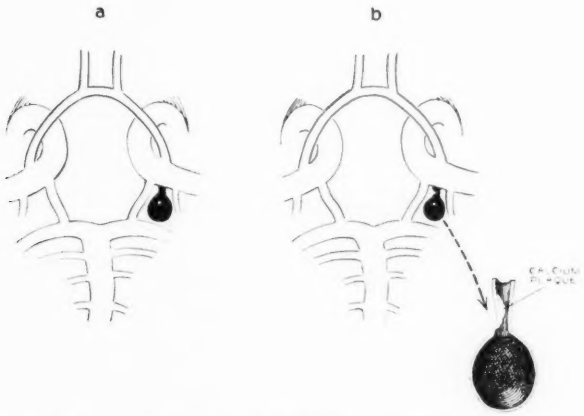


FIG. 19. *a*, Sketch illustrating usual site of vestigial remnant aneurysm. *b*, Appearance in neck of a vestigial aneurysm involved with a calcium plaque.

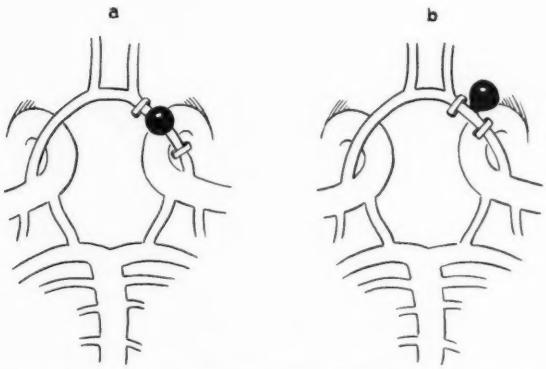


FIG. 20. *a* and *b*, Trapping of aneurysms of the main trunk of the anterior cerebral artery regardless of whether they are fusiform or pedunculated.

## ANEURYSMS ARISING FROM THE ANTERIOR COMMUNICATING ARTERY

Aneurysms of the anterior communicating artery present a particular problem. Unfortunately, the anterior communicating artery is an arterial communication, of only a few mm. in length, between the two anterior cerebral arteries. An aneurysm of any size involves the entire length of the artery. Here again, the aneurysm usually arises from the junction of either

nterior cerebral artery with the anterior communicating artery (Fig. 21, and *b*). Arteriography is of utmost importance to determine from which nterior cerebral artery the aneurysm seems to arise, or from which anterior erebral artery it derives most of its blood supply. If the angiograms dem-

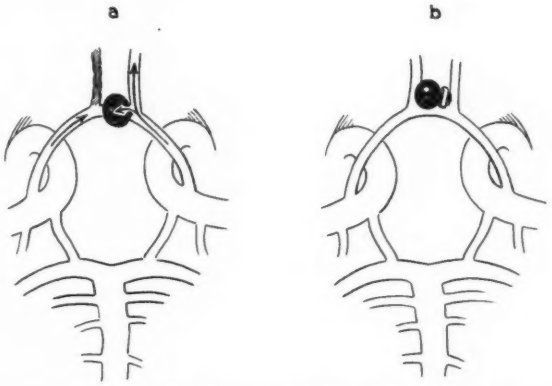


FIG. 21. *a*, Aneurysm at bifurcation of anterior cerebral and anterior communicating arteries, its neck arising from the right anterior cerebral artery, and spontaneous thrombosis of left anterior cerebral artery. Arteriograms demonstrated filling only from right side. *b*, Pedunculated aneurysm suitable for occlusion with silver clip, allowing normal circulation in both anterior cerebral arteries.

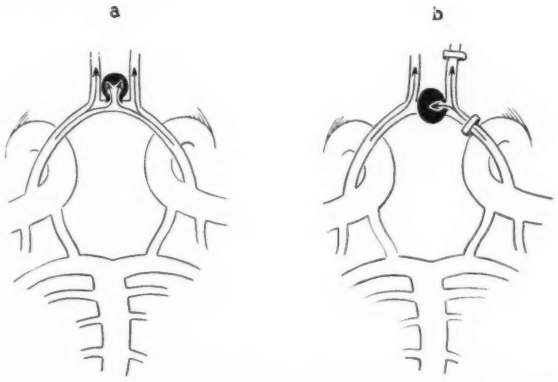


FIG. 22. *a*. Aneurysm of the anterior communicating artery with equal blood supply from both anterior cerebral arteries. *b*, Filling of aneurysm from only one side. The silver clips are attached proximally and distally on the anterior cerebral artery which feeds the aneurysm.

onstrate that the contrast medium fills the aneurysm only from one side (Figs. 22 *b* and 23), occlusion of the anterior cerebral artery proximal and distal to the aneurysm is the procedure of choice. If the aneurysm is pedunculated and is sufficiently large, a silver clip should be placed on its neck (Fig.

21 *b*). In none of the patients in this series was this possible.

If the aneurysm fills equally well from each anterior cerebral artery (Fig. 22 *a*) the aneurysm should not be subjected to direct surgical attack. It is almost impossible to mobilize such an aneurysm safely without rupture or, if this could be done, it would be necessary to sacrifice both anterior cerebral arteries and thus produce a bilaterally lobotomized patient. This procedure is attended with more profound mental changes owing to the occlusion of the callosal vessels in addition to sacrifice of both anterior cerebral arteries. In 2 patients thrombosis of the contralateral anterior cerebral artery (Fig. 21 *a*) was noted. The right arteriogram demonstrated that the aneurysm filled adequately; the left arteriograms, on repeated attempts, did not visualize the anterior cerebral artery. Occlusion of that anterior cerebral artery was verified by operation. The ipsilateral anterior cerebral artery distal to the aneurysm may also become occluded spontaneously, either as a result of vasospasm from trauma caused by the aneurysm itself or by disease in the wall of the artery as well as in the aneurysm. In the latter instance, occlusion of the anterior cerebral artery shortly after it leaves the internal carotid artery is indicated.

FIG. 23. Actual surgical specimen demonstrating aneurysm at bifurcation of anterior cerebral and anterior communicating arteries.

## ANEURYSMS ARISING FROM THE MIDDLE CEREBRAL ARTERY

Non-pedunculated aneurysms of the main trunk of the middle cerebral artery cannot be trapped or ligated without disastrous results (Fig. 24).

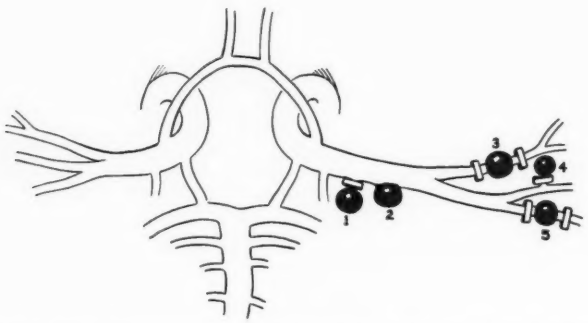


FIG. 24. Various types of aneurysms at different locations on the middle cerebral artery: (1) pedunculated type suitable for occlusion; (2) aneurysm with outpouching unsuitable for local excision; (3) branch of middle cerebral artery which may be sacrificed; (4) pedunculated type which may be excised; however, a fusiform aneurysm would cause considerable disability; (5) temporal branch which may be sacrificed.

Fortunately, a few aneurysms arise from the middle cerebral artery after it has divided. Arteriography, again, is essential to determine whether the aneurysm arises from a branch that may be sacrificed without causing permanent invalidism.

### ANEURYSMS ARISING FROM THE POSTERIOR COMMUNICATING ARTERY

The posterior communicating artery is infrequently involved; this occurred in only 2 of the 143 patients. If a small aneurysm does arise from the posterior communicating artery, it can either be excised or trapped, as in Fig. 9. If, however, the aneurysm involves the entire posterior communicating artery, surgical trapping or excision can only meet with disaster. I have no suggestions for treatment of this particular type of aneurysm unless consistent filling is demonstrated by either carotid or vertebral arteriograms. If it can be demonstrated that only one of these fills the aneurysm, ligation of that particular vessel might be considered. Fortunately, aneu-

FIG. 25. Dissecting aneurysm involving the angular branch of the middle cerebral artery. *Inset*, Specimen following removal.

rysms of the posterior communicating artery occur rarely. Many aneurysms reported and thought to arise from the posterior communicating artery represent aneurysms in vestigial embryonic arterial remnants.

## DISSECTING INTRACRANIAL ANEURYSMS

Two dissecting aneurysms (Figs. 25 and 26) were found in this group. I have been unable to find previous reference to this particular type of intracranial aneurysm in the literature. The type of treatment depends entirely upon the location. As shown in Fig. 25, the aneurysm was located in a region that was readily accessible for complete excision. In Fig. 26 however, since the aneurysm involved the medial trunk of the middle cerebral artery, excision would have been followed by severe incapacitation. Ligation of the internal carotid artery was performed, with complete relief of symptoms up to the present time (8 years).

FIG. 26. Dissecting aneurysm of the middle cerebral artery.

## ANEURYSMS THAT HAVE RUPTURED INTO THE CAVERNOUS SINUS

Many lives are saved by the rupture of an aneurysm into the cavernous sinus rather than into the subarachnoid space. The clinical manifestations are intriguing. A bruit is present, either objectively or subjectively, in all instances. A pulsating exophthalmos is not necessarily present in all instances. In 1 patient the pulsating exophthalmos was present on the side opposite the communication between the aneurysm and the cavernous sinus. The reason for this is that much depends on the actual site of the fistula in the cavernous system (Fig. 27), and also on the relationship of the bulk of the aneurysm to the sinus and fistula. If the intracavernous aneurysm is centrally placed with only slight compression of the venous channels the arterial blood may flow in either direction (Figs. 28 and 29). A large subclinoidal aneurysm occluding the cavernous sinus unilaterally with the fistula pointed posteriorly will fill the posterior intercavernous, basilar and petrosal sinuses (Fig. 30). A fistula in the medial anterior portion will cause

the arterial blood to rush into the anterior intercavernous sinus, causing an exophthalmos on the opposite side.

The treatment consists of ligation of the internal carotid artery in the neck, and intracranially distal to the fistula. In certain patients with persistent exophthalmos following ligation it may be necessary to excise large aneurysmal intraorbital veins after unroofing the orbit. This can readily

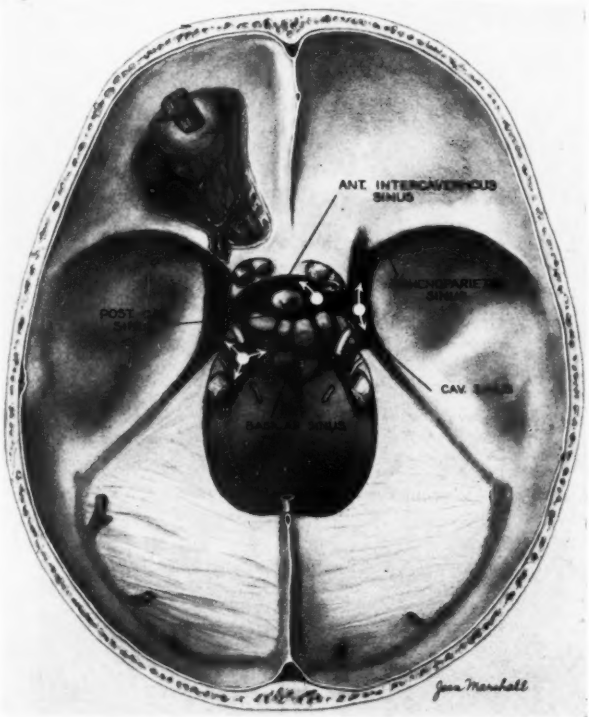


FIG. 27. The directions are shown in which the arterial blood will flow in the cavernous system, depending entirely on the site of the fistulous opening as indicated by the circular dots. The flow also depends on the size of the aneurysm and the extent to which it has occluded the sinus.

be done at the time of the intracranial carotid ligation. This procedure was necessary in 3 patients in whom the exophthalmos did not subside following extracranial and intracranial ligation, because of thrombosis of the superior and inferior ophthalmic veins.

## ANEURYSMS OF THE VERTEBRAL ARTERY

Trapping or excision is the procedure of choice if the opposite vertebral artery supplies adequate collateral circulation. The smaller aneurysms can

FIG. 28. Large subclinoidal aneurysm with arterial blood flowing in all directions: (1) a large superior ophthalmic vein; (2) the beginning of the inferior ophthalmic vein and (3) the aneurysm and cavernous sinus filled with dye.

FIG. 29. Aneurysm ruptured into the cavernous sinus with arterial blood entering mainly the sphenoparietal sinus and sylvian veins.

be attacked in this manner; however, large saccular aneurysms may be completely inoperable with the exception of ligation of the vertebral artery on the ipsilateral side. Fusiform aneurysmal dilations in most instances are not amenable to surgery or any other form of treatment.

## ANEURYSMS OF THE BASILAR ARTERY

Fusiform aneurysmal dilatations of the basilar artery are common. Surgical intervention is of no help nor can large saccular aneurysms be attacked surgically with any degree of safety.

It is conceivable that if the anastomosis of the internal carotid artery to

FIG. 30. Aneurysm with rupture into the basilar sinus.

the jugular vein in the neck bilaterally proves to be practical in the adult or if vertebral arteriovenous anastomosis is practical, aneurysms of the branches of the basilar artery could be excised or trapped if their size does not make the procedure prohibitive.

## ANEURYSMS WITH RUPTURE INTO SOFT TISSUE OR VENTRICLE

Rupture of an intracranial aneurysm occurs most frequently into the subarachnoid spaces. In 12 patients, however, the hemorrhage extended into the soft tissues of the brain, most frequently into the temporal lobe (Fig. 31). The intracerebral hemorrhage in 2 patients ruptured into the lateral ventricle.

This complication is perhaps due to thickening of the arachnoid around the aneurysm because of local irritation, the adhesions preventing the hemorrhage from entering the subarachnoid spaces. The site of the aneurysm

influences to a great extent the occurrence of intracerebral bleeding. Aneurysms of the branches of the middle cerebral artery frequently are the sources of intracerebral hemorrhage.

## ANEURYSMS ASSOCIATED WITH ESSENTIAL HYPERTENSION

Any patient who has an intracranial aneurysm associated with marked hypertension should be subjected to thoracolumbar sympathectomy and ligation of the internal carotid artery if other medical measures are insufficient to keep the blood pressure within reasonable limits.

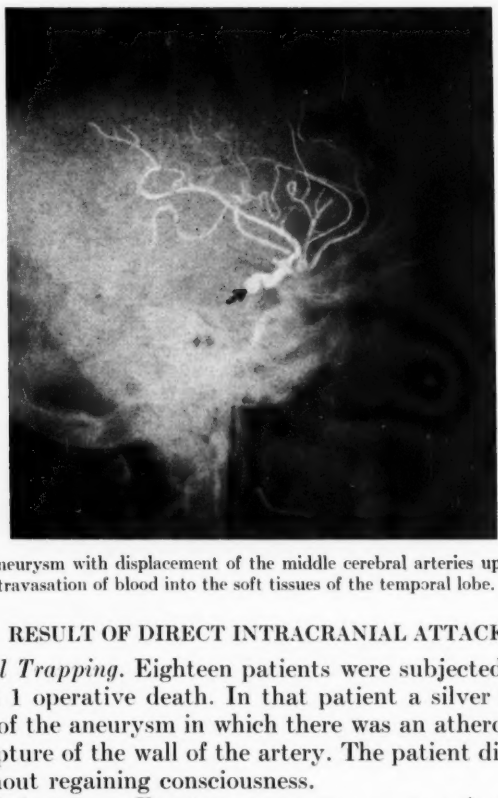

FIG. 31. Vestigial aneurysm with displacement of the middle cerebral arteries upward and anteriorly, owing to extravasation of blood into the soft tissues of the temporal lobe. (Retouched)

## RESULT OF DIRECT INTRACRANIAL ATTACK

*Intracranial Trapping.* Eighteen patients were subjected to intracranial trapping, with 1 operative death. In that patient a silver clip was placed over the neck of the aneurysm in which there was an atheromatous plaque, resulting in rupture of the wall of the artery. The patient died 8 hours after operation without regaining consciousness.

*Excision of Aneurysm.* Fourteen aneurysms were excised intracranially, with 2 operative deaths. The aneurysms were located at the bifurcation of the internal carotid artery and middle cerebral artery. One of the patients, however, was in extremis at the time the surgical procedure was instituted because of bleeding.

*Exposure of Aneurysm Intracranially with Attempted Mobilization and Excision.* Four large aneurysms in the circle of Willis were exposed in an

attempt to mobilize them for excision or trapping. The execution of this was prevented by the size of the aneurysm. Three patients died as a result of exposure and mobilization of the aneurysm. The 4th patient died 6 months later.

*Large Intracranial Aneurysms Arising from the Circle of Willis.* Four large intracranial aneurysms arising from the circle of Willis in the parasellar region, supraclinoidal in position, were exposed. A great portion of the organized clot was removed from the aneurysmal sac, muscle was inserted into the evacuated area and the wall of the aneurysm imbricated with black silk. This resulted in 1 operative death, the patient dying 1 day following dismissal from the hospital from a sudden fatal hemorrhage. Two subsequent deaths occurred, 1 patient dying in 1½ years and the other 3 years following this procedure. One patient has survived for over 12 years.

## COMMENT

It may be noted that intracranial trapping, whenever feasible, is attended with a low mortality as well as a cure; the one exception was the patient who died 1 year after operation from a subarachnoid hemorrhage from an unsuspected aneurysm on the opposite side. It is not justifiable, therefore, to institute surgery of any type in these patients without demonstrating to the best of one's ability the absence of multiple or bilateral aneurysms. The excision of aneurysms also is attended with a reasonably low mortality if aneurysms that arise from the bifurcations are not included. For that reason I strongly recommend great caution before decision is made to attack an aneurysm that arises from a bifurcation unless a suitable neck for the application of a silver clip can be demonstrated.

It is my impression that evacuation of a portion of organized clot from a large intracranial aneurysm has no particular merit either in relieving symptoms or in prolonging life. Most of these patients would have done as well with ligation as indicated by the results obtained from ligation of the internal carotid artery in subsequent patients in whom similar aneurysms were found. It is worthy of note, however, that the patients who died following exposure of the aneurysm and imbrication of the wall over muscle tissue did not have ligations of the internal carotid artery. Of the patients who survived, the internal carotid artery had been occluded by ligature. It is possible that in a few instances in which the local symptoms are grave, ligation followed by evacuation and support by muscle might be worth while.

Exposure of a large intracranial aneurysm directly attached to the circle of Willis should be discouraged in all cases.

Death occurred in patients who were not carefully chosen; in patients in whom the aneurysm was exposed before arteriography became a routine diagnostic procedure and in patients in whom the site of the aneurysm precluded surgery.

Only one reference has been included although several valuable publications have

appeared in the literature. Since the opinions voiced in this publication are based entirely on a personal surgical experience with 143 patients, references have been purposely omitted. Since completion of this paper a total of 164 verified intracranial aneurysms have been treated surgically.

## REFERENCE

1. Rogers, L. Carotid ligation for intracranial aneurysm. Report of a case studied by electro-encephalography. *Brit. J. Surg.*, 1944, *32:* 309–311.

# OBSERVATIONS ON RESECTION OF THE SUPERIOR LONGITUDINAL SINUS AT AND POSTERIOR TO THE ROLANDIC VENOUS INFLOW

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THE problem of resection of the superior sagittal sinus is an exceedingly important one if we realize that many meningiomas arise from this structure and that their complete removal is usually impossible without removing a portion of it with the tumor. These tumors are benign and, since they lie readily accessible to the surgeon, their complete extirpation with permanent cure becomes a problem of paramount concern to the neurosurgeon. With our accumulated knowledge of the postoperative reaction of the patient to the ligation of this vessel it should now be possible to completely and permanently cure these patients with a negligible operative mortality.

My first object in this discussion is to present evidence to show that under certain conditions the superior longitudinal sinus, previously unoccluded by a tumor, may be safely ligated and resected between the rolandic venous inflow and the torcular Herophili. In this location the cortical venous return to this sinus is scant in comparison to that found in the more anterior midline areas of the cortex, so that any physiological upset caused by closure of the superior longitudinal sinus at this point should be due entirely to that caused by the closure of the sinus itself and not to ligation of tributary veins.

In 1942 I reported 10 cases of resection of the superior longitudinal sinus at various points, 9 of them without serious effect.[1] Five of these were at or posterior to the rolandic inflow but they had completely occluded sinuses. One patient died in whom an unoccluded sinus was ligated at the rolandic inflow. This is the only case reported in the literature of resection at or back of the rolandic inflow before occlusion had occurred. My second object is to present a second fatal outcome where an incompletely occluded superior longitudinal sinus was ligated and resected at the rolandic inflow.

From my 10 cases and 15 others reported in the literature I concluded that: "The superior longitudinal sinus can be ligated or resected safely anterior to the point where the rolandic veins enter the sinus without regard to whether or not a tumor is compressing or occluding this structure. It also appears safe to remove a portion of the sinus at or back of the rolandic veins provided the sinus has already been slowly occluded by a tumor growth. A death following resection of an unoccluded superior longitudinal sinus at the entrance of the rolandic veins would indicate that the procedure is incompatible with life."

No evidence existed at that time regarding the probable effect of resecting an unoccluded sinus between the rolandic inflow and the torcular. The cases I shall present here should greatly help in solving the problem of complete removal of the parasagittal meningiomas.

*Case 1. Resection of unoccluded superior longitudinal sinus posterior to rolandic venous inflow for complete removal of parasagittal meningioma.*

A man of 49 years was admitted to the Jefferson Hospital neurological service of Dr. Bernard J. Alpers on July 28, 1943. His chief complaint was "pain in the back of the neck and head."

In 1912 and 1938 he suffered rather severe head blows; he was not unconscious, but had severe headaches each time for a day or so. During most of his life he had had dizzy spells, usually occurring when he arose from a sitting position. Six weeks prior to admission pain developed in the back of the neck which extended to the top of his head and into his eyes. These headaches came on in attacks lasting from several minutes to several hours, during which he perspired profusely and his face and shoulders became flushed. For a week before admission the attacks had occurred daily. For many years he had had blurring of vision which he described very inaccurately. There had been some progressive weakness in the arms and legs and on the day before coming to the hospital he had been unable to walk because of this. For several days he had vomited repeatedly and felt nauseated constantly.

*Examination.* He was a mildly confused, irritable, thin man with definite slowing of response and impaired memory. He walked with a wide base and slightly unsteadily. There was 5 D. choking of the right disc and 3 D. on the left. There was a left homonymous hemianopsia. The left side of the face was flattened, there were weakness and dyssynergia of the left arm and he was unable to stand alone on either leg. The left biceps was more brisk than the right. Position sense was impaired in the left great toe. The diagnosis of a right occipitoparietal tumor was made and this clinical location was verified by the roentgenographic finding of a calcified mass in this region near the midline.

*1st Operation.* On Aug. 8, 1943 a craniotomy was performed with the opening to within $\frac{1}{2}$ inch of the midline (Fig. 1). A fairly dense meningioma, weighing 98.5 gm., was found. This was covered by a thin layer of brain and was attached to the superior longitudinal sinus by a base about $\frac{3}{4}$ inch in diameter. It was removed without incident and excised from its attachment to the sinus. By palpation it was determined that a portion had infiltrated through the sinus wall into its lumen, but I could not make certain as to whether or not it had completely occluded the sinus. He was not in good condition for operation and it was thought best to thoroughly expose and explore the sinus at another operation.

*Course.* His immediate convalescence was uneventful and at the end of 3 months he appeared in excellent health with the exception of a homonymous hemianopsia which seemed to cause him no trouble.

*2nd Operation.* On Nov. 1, 1943 a supplementary bone flap was turned across the superior sagittal sinus so as to thoroughly expose it and the adjacent left cortex (Fig. 1). The sinus was isolated by cutting through the dura and entirely up to it on either side of the tumor stub. The tumor base was about $\frac{3}{4}$ inch by 1 inch and had infiltrated only the right wall of the sinus. Palpation between the thumb and forefinger gave the sense of a nodule completely occluding the sinus channel. It was unnecessary to ligate any cortical veins on either side. The sinus was transfixed by sil

sutures and ligated anterior and posterior to the tumor. About 2 inches of the vessel was removed. The dura was sewed to the falx on the left and on the right it was closed with alantoid membrane and the bone flap replaced. It was unnecessary to disturb the previously made bone flap at this operation.

*Course.* Convalescence was uneventful and at the present time he is entirely well with the exception of the homonymous hemianopsia, but this does not prevent him

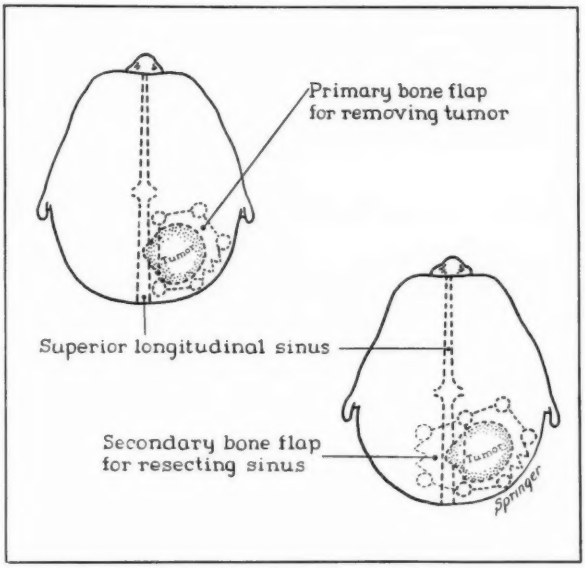


FIG. 1. *Case 1.* Showing craniotomy flap made to adequately uncover the tumor and the superior longitudinal sinus.

from carrying on an active business as a successful contractor with unusual responsibilities.

*Pathological Study.* When the specimen was dissected an open channel was found to pass by a large tumor nodule in the sinus (Figs. 2 and 3). Venous blood unquestionably passed through the vessel but to what extent as compared with the normal flow through it, I am unable to say. The size of the tumor in relation to the interior of the sinus is best shown by a drawing from the specimen (Fig. 3B). The tumor microscopically was a meningioma containing many psammoma bodies.

*Case 2. Resection of meningioma with the superior longitudinal sinus at the rolandic inflow, with fatal outcome.*

This 39-year-old man was transferred to the neurosurgical service of Jefferson Hospital from the Department of Neurology under Dr. Bernard J. Alpers on Sept. 14, 1944. He had been previously operated upon in December 1943 by another surgeon with the partial removal of a parasagittal meningioma of the left parietal region. Immediately following that operation he continued to suffer from marked right

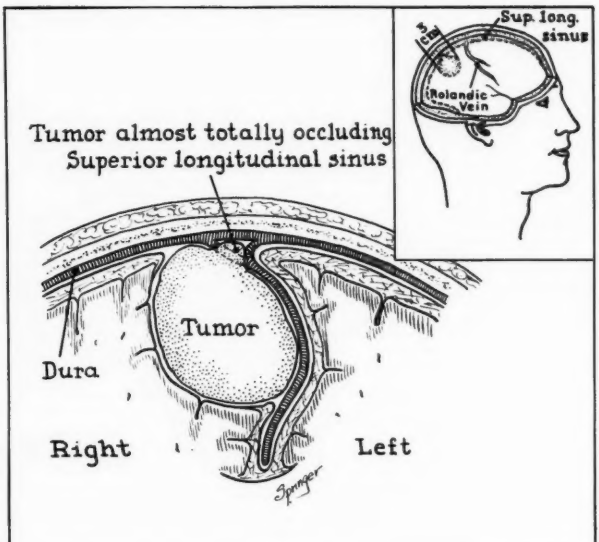


FIG. 2. *Case 1.* Sketch to show location of tumor and part of sinus removed.

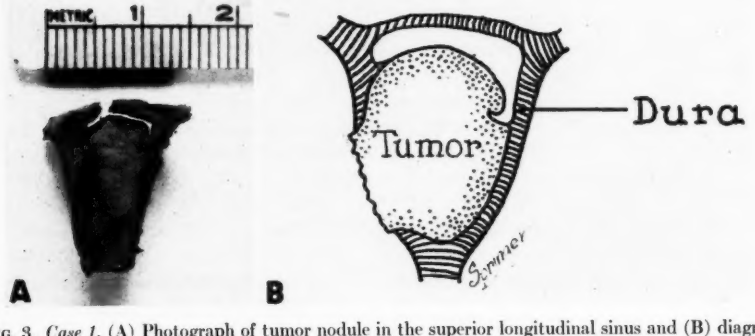


FIG. 3. *Case 1.* (A) Photograph of tumor nodule in the superior longitudinal sinus and (B) diagram of cross section of the sinus, which has not been completely occluded by the tumor.

hemiparesis. He had been able to get up and around but was entirely incapacitated as far as a gainful occupation was concerned. His weakness continued to increase and he was having rather severe persistent headaches.

*Examination.* There was a marked weakness involving the whole right side, more in the right leg and arm, both of which were almost entirely useless, although he was able to barely stand. There were the usual neurological phenomena associated with a left cortical lesion, but there was no visual field defect. CSF pressure was reported to be 232 mm. He was mentally alert and had only a slight speech defect. There was a large scar in the left frontal region extending back into the midparietal area.

Through this opening a meningioma had been removed but the exact procedure was not recorded and there was no note as to how much of the growth had been actually removed. Since this man was practically helpless it seemed necessary to make another attempt to remove the tumor in order to save his life.

*1st Operation.* On Sept. 25, 1944 the old bone flap was raised. This disclosed a very vascular meningioma composed of two lobes, an anterior one being about 2 inches in diameter which was connected by a constricted part of the tumor to a second portion approximately 2½ inches in diameter. Both of these lay tightly against the superior longitudinal sinus at the midparietal area and precisely where the rolandic vein passed from the cortex into the longitudinal sinus. With a great deal of difficulty, because of severe hemorrhage, the tumor was entirely isolated from the brain by ligating all of the cortical vessels fastened to it. This exposed the attachment to the superior longitudinal sinus, which appeared to be about 4 cm. in length. The volume of the tumor was considerably reduced by coagulation of the vessels going into it. The dura was closed and the bone flap replaced.

*2nd Operation.* On Nov. 3, 1944 a bone flap was turned down across the superior longitudinal sinus and directly over the tumor at its attachment to the sinus. There was very troublesome hemorrhage from the veins permeating the dura and the operation was concluded after controlling this bleeding.

*3rd Operation.* On Nov. 10, 1944 a newly formed bone flap was raised across the midline. The dura was then sectioned about 1 cm. from the sinus along the right side and over the length of the tumor which could be palpated encroaching on it. A similar incision was made parallel to the sinus on the left side. Before ligating the right cortical vessels the sinus was palpated between the thumb and forefinger and while there was no presenting tumor to the right side of the sinus, it was felt the mass had completely occluded the lumen of this vessel. This proved later to be an erroneous observation. It was possible now to lift the tumor mass at its anterior end thereby isolating the sinus for ligating at this point. Transfixation sutures were passed around the sinus and it was cut between. By sectioning the falx beneath the tumor, the tumor with the resected part of the sinus was raised until well posterior to the infiltration of the sinus wall, where it was again ligated and resected. Prior to the resection all of the large veins passing from the rolandic area on the right to this sinus were coagulated. There were two very large ones. This was performed without trauma to the right cerebral cortex. The dural defect was closed with cargile membrane, the bone flaps were replaced and the skin was closed with silk.

*Pathological Study.* The tumor was found to be a very vascular, boggy meningioma which had been greatly reduced in size by the surgical manipulation. In its undisturbed size it appeared to be at least 3½ inches in length and 2 inches in diameter at one end and about 2½ inches at the other. It was attached to the sinus over a length of about 3 cm. When the sinus was opened longitudinally it was found that one nodule, about 5 mm. in diameter, had perforated the sinus wall and was protruding into it, but it was not sufficiently large to entirely occlude the flow of blood through this structure (Figs. 4, 5 and 6).

*Course.* The following day his condition was excellent. He was able to talk freely. The strength in the right leg and arm was good. On the 2nd postoperative day he was slightly drowsy and had a rather hard convulsion. His fever rose to 101° and his pulse rate increased somewhat. CSF showed only red blood cells. The 3rd day he was more stuporous and apparently unable to move the right arm and leg, and he had a temperature of 103° with a fast pulse. His condition grew rapidly worse and

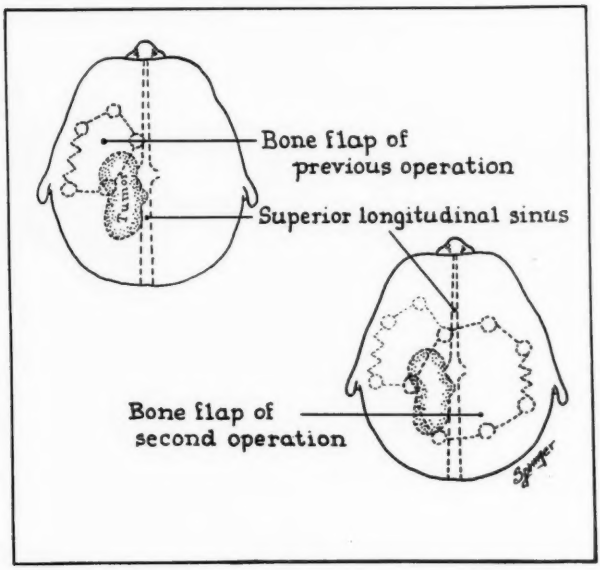


FIG. 4. *Case 2.* Craniotomy flaps used to expose tumor and sinus.

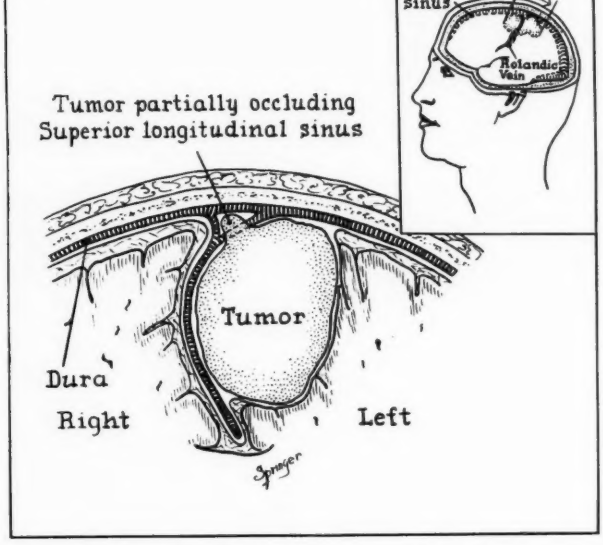


FIG. 5. *Case 2.* Sketch to show location of tumor and part of sinus removed.

he died at the end of the 4th postoperative day. Unfortunately, necropsy was not permitted.

The outcome of this case was in keeping with the impression given in a previous communication by the author where the removal of a small meningioma, which had not occluded the superior longitudinal sinus but which required the ligation of the sinus with the rolandic veins, ended fatally. The same error in observation was made in this case as in the previous one in that it appeared as though the sinus was entirely occluded. It has now been shown definitely in two instances that ligation of an unoccluded superior longitudinal sinus at the rolandic inflow is dangerous. It is absolutely necessary to determine the patency of the sinus prior to its resection. It should be possible to determine whether or not this vessel is occluded by injecting the sinus anterior to the point of occlusion with a radiation-opaque material such as diodrast, sodium iodide or thorotrast and with roentgenography on the operating table, using a portable machine. Another way to determine its patency would be to open the sinus and insert a probe, or perhaps better still a small ureteral catheter into the sinus past the mass. The danger here would be the entrance of air through any opening one might make in the sinus. If the vessel is not completely occluded, then of course that part of the tumor involving the sinus wall must be left in place.

FIG. 6. *Case 2.* Specimen removed at operation. Note small nodule (arrow) protruding into sinus but not large enough to occlude it.

## SUMMARY

Two cases are reported of resection of the superior longitudinal sinus where this vessel had not been completely occluded by invading meningiomas. The first patient had the sinus resected between the rolandic cortical venous inflow and the torcular Herophili. This one fully recovered. The second patient, in whom the sinus was resected at the inflow of the rolandic veins, died on the 4th postoperative day presumably from venous congestion and brain edema.

## CONCLUSIONS

From these 2 cases and others previously reported in the literature it would seem that ligation or resection of the superior longitudinal sinus can be performed at any point that does not require the ligation of the unobstructed rolandic inflow of cortical veins into the sinus.

## REFERENCE

1. JAEGER, J. R. Ligation and resection of the superior longitudinal sinus. *Arch. Neurol. Psychiat., Chicago*, 1942, *48:* 977–986.

# COMPLICATIONS OF ANGIOGRAPHY

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THE short history of cerebral angiography reveals a constant search for an inert, more miscible contrast medium that is devoid of untoward side reactions. None of the substances thus far used have been free of adverse reaction. The first practical radiopaque material used was 25 per cent sodium iodide. Egas Moniz[10] carried out all angiography with this until 1931. Many complications were seen with this material and his mortality rate was between 2 and 3 per cent. Thorotrast was introduced at about this time and became a very popular substance, although its use was mainly confined to the continent. Complications with this substance were reported by Ekström and Lindgren[4] and Northfield and Russell.[11] The potential danger of radioactivity served to limit its use in this country. Gross[6,7,8] introduced diodrast in 1939 and, in the 35 per cent solution, it is now perhaps the most widely used of the contrast media. Relatively few complications with this substance have been reported in the literature. Engeset[5] reported 2 fatalities in a series of 100 patients and in neither case did he feel that death was due primarily to angiography. Bull[1] reported 3 deaths in a series of 1,000 cases, all of which were complicated by large intracranial tumors. Chusid, Robinson and Margules-Lavergne[2] reported 2 cases of transient hemiplegia. Dyke[3] reported a case of thrombosis of the carotid artery. Urticarial reactions have been seen. In the main, however, the literature emphasizes the relative safety of the procedure. Indeed, in Torkildsen's recent monograph[13] on 2,000 cases of angiography, no major complications nor death have been listed.

The authors have seen a rather wide variety of adverse reactions to diodrast angiography and would like to emphasize its potential hazards. The present study is based on a series of 147 carotid angiograms performed with 35 per cent diodrast on 108 patients in the years 1946 to 1950. The series constitutes 30 cases of brain tumor, 17 of aneurysm, 19 of subarachnoid hemorrhage, 12 of cerebral thrombosis, 7 of degenerative disease, 4 of subdural hematoma and 19 undiagnosed cases. Complications occurred in 14 of the 108 cases.

## COMPLICATIONS

### I. FATAL (*3 cases*)

Death occurred in 3 cases in which cerebral angiography contributed, at least in part, to the cause of death.

*Case 1.* M. J., a 35-year-old female with renal hypertension, was admitted to the

neurosurgical service with diplopia, blurred vision and focal seizures associated with loss of consciousness. Examination was essentially negative except for cardiac enlargement and B.P. of 244/160. Percutaneous angiography under local anesthesia with premedication of 0.4 mg. nembutal and 40 mg. atropine revealed inadvertent filling of the left vertebral artery after an injection of 10 cc. of 35 per cent diodrast. A 2nd injection into the carotid artery gave satisfactory films. The patient was subdued and uncommunicative following this procedure. Twelve hours after angiography, she rather suddenly expired from respiratory failure. At autopsy approximately 250 cc. of blood were found in the neck, deviating the trachea to the opposite side but not obstructing it (Fig. 1). In addition to marked kidney pathology, con-

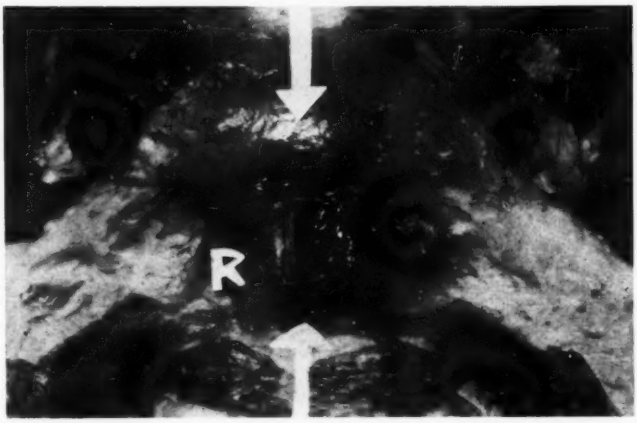


FIG. 1. *Case 1.* Postmortem neck dissection, showing deviation of trachea to the right and hemorrhage into the neck. Patency of airway tube seen through midline incision in the trachea.

siderable cerebral edema was present. It was the feeling that the extravasation of blood into the neck had caused bilateral jugular compression and secondary venous stasis in the brain and that this, in turn, led to edema and respiratory failure of central origin.

*Case 2.* C.O., a 65-year-old female, was admitted because of a fracture of her right femur. B.P. 128/86. She was seen in consultation because of a rather marked exophthalmos and mental confusion. History revealed that 12 years previously she had noted the onset of exophthalmos and left 3rd nerve paralysis. Surgery had been refused. On examination an additional left 4th and 7th nerve paralysis and a left Foster Kennedy syndrome were found. Skull x-rays confirmed the impression of a sphenoid wing meningioma. Bilateral percutaneous angiography under local anesthesia with 0.4 mg. atropine and 250 mg. sodium luminal was carried out with a total of five 10 cc. injections on the right and two 10 cc. injections on the left. It was noted that the patient was less responsive after this procedure but it was not felt to be related directly to the angiography. Because of previous poor filling on the left side, an open angiogram was performed 2 days later with 50 mg. of demerol and 4 mg. of atropine as premedication, and a total of 50 cc. of 35 per cent diodrast was injected on the left. The patient deteriorated rapidly within the next 24 hours and expired

the following day. Autopsy revealed a large sphenoid wing meningioma engulfing the internal carotid and part of the middle cerebral artery and, in addition, a large, fresh hemorrhagic and necrotic area in the cortex along the distribution of the middle cerebral artery (Fig. 2).

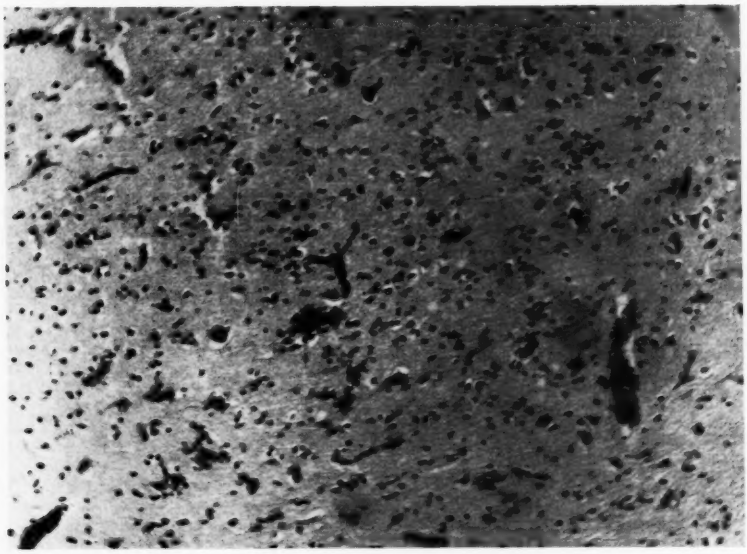

FIG. 2. *Case 2.* Section of the left posterior frontal lobe cortex, showing an area of acute infarction with congestion of blood vessels and perivascular infiltration. Cellular architecture is still intact but individual cells are shrunken.

*Case 3.* L.S., a 54-year-old male, had a 7-year history of alternating hemiplegia, previous ligation of left common carotid artery at another hospital and progressive bilateral pyramidal tract signs, generalized tremor, mental deterioration and emotional lability, culminating in another total left hemiplegia on the day of admission. B. P. was 150/90 and his heart was slightly enlarged to the left. In spite of previous ligation of the left common carotid artery, a percutaneous angiography was carried out on the right with 100 mg. of nembutal and 60 mg. of codein as premedication. Immediately following the 1st injection of 10 cc. of 35 per cent diodrast, the patient became unconscious; respirations became labored and assumed a Cheyne-Stokes character. Stellate block was done immediately with improvement in respirations. The pre-existing left hemiparesis remained unchanged; the patient never regained consciousness and died on the 12th day with terminal hyperpyrexia and respiratory failure. Autopsy revealed multiple recent and old infarcts of the brain. The left vertebral artery was enlarged and thrombosed and there was some generalized atrophy of the brain.

Cases 2 and 3 represent rather massive cerebral infarction in individuals whose cerebral circulation was already impaired. It is of some interest to

ote that death was delayed from 2 to 12 days following angiography. Case represents an error in surgical technique and judgment inasmuch as a ervical hematoma was suspected but not drained prior to her death.

II. NON-FATAL, PERMANENT (*4 cases*)

*Case 4.* E.T., a 55-year-old female, was admitted because of 3 grand mal seizures ver the previous 3 months. Neurologic and cardiac status were negative. B.P. 30/98. Left percutaneous angiography failed to fill the carotid system. Five days ter left open angiography was done under local anesthesia with 0.4 mg. atropine, 0 mg. demerol and 200 mg. nembutal as premedication. A generalized convulsion llowed the 1st injection of 10 cc. of 35 per cent diodrast into the left internal carot- l artery, with residual aphasia and right hemiparesis. Transitory right facial focal izures occurred the following day and the stupor and aphasia continued. Two ays later an exploratory craniotomy revealed a rather massive infarct of the poste- or frontal and temporal lobes with softening and swelling but no tumor or hemor- hage. The patient gradually improved and at the end of 1 month was able to walk ith approximately 75 per cent function, but aphasia and mental aberration per- isted to a diminishing degree over the ensuing 2 years.

*Case 5.* E.V., a 35-year-old female, had a spontaneous subarachnoid hemorrhage with sudden collapse on the morning of admission. There had been 2 previous episodes of severe transient headaches. Lumbar puncture yielded a pressure of 520 and grossly bloody CSF. The patient improved under conservative treatment until 1 week later when she had a 2nd episode, this time associated with left facial and hand weakness and a left ptosis. An open right carotid arteriography was performed 3 days later under local anesthesia with 0.4 mg. atropine, 200 mg. nembutal and 80 mg. demerol as premedication. Four 15 cc. injections of the right internal carotid artery were made with 35 per cent diodrast. The next morning, hemiplegia and left homonymous hemianopsia were apparent. Her eyes were deviated to the right and she became drowsy with progressive deterioration, disorientation and incontinence as well as left-sided hypertonicity and right-sided weakness. This state continued for 2 days when a ventriculogram revealed no evidence of a space-occupying lesion but symmetrical dilatation of the ventricles. At the time of discharge 1 month later she was not sufficiently oriented to be able to care for herself. Since then, she has continued to improve slowly in motor function and less so in mental status.

*Case 6.* B.T., a 44-year-old male, was admitted because of a sudden onset of generalized headache, vomiting and dizziness, not associated with loss of consciousness. There had been a similar episode approximately 2 years previously. Lumbar puncture yielded grossly bloody CSF with an initial pressure of 250. Neurological and cardiac findings were essentially negative. B.P. 124/60. The CSF began to clear after 10 days, at which time percutaneous angiography was attempted under local anesthesia and poor filling obtained on 2 occasions. One week later right open internal carotid angiography was done under local anesthesia with 100 mg. demerol and 300 mg. seconal for premedication. A total of 45 cc. of 35 per cent diodrast was injected with good filling but no evidence of aneurysm nor ill effects. One week later left open arteriography was performed under local anesthesia with 200 mg. nembutal as premedication, using 75 cc. of 35 per cent diodrast in a series of 5 injections. Three hours later the patient became confused and aphasic and a right hemiparesis de-

veloped. His condition progressed to a moribund state and for 12 hours it was critical. He received stellate blocks and the carotid artery was stripped of its sympathetic fibers. There was no immediate improvement from either procedure but the following day the patient gradually began to improve. At the time of discharge 1 month later he had gross clumsiness of right leg with increased deep tendon reflexes and a mild expressive aphasia. After 2 years he has returned to full-time work as a telephone executive with a residual minimal slurring of speech and clumsiness of extremities.

*Case 7.* L.S., a 30-year-old male, was admitted with a 16-year history of episodic headache and visual disturbance. B.P. was 115/60. Cardiac limits were normal. Right percutaneous carotid angiography was done under local anesthesia without premedication, using a total of 24 cc. of 35 per cent diodrast in 3 injections. A complete left hemiplegia, lasting approximately ½ hour, followed the 3rd injection, with gradual return to normalcy in 14 days although a persistent paresthesia of the left leg has continued to date.

Three of these 4 patients exhibited serious neurological deficits following angiography. Although the onset of symptoms was delayed in all but 1 case, the nature of the complications, with pathological confirmation in 1 case, suggests that their occurrence was more than coincidental.

### III. NON-FATAL, TRANSIENT (*7 cases*)

#### (A) *Transient Hemiplegia.*

*Case 8.* C.B., a 43-year-old female, was admitted because of mild headaches during the previous 8 months. Examination revealed a right exophthalmos with a normal cardiac status. B.P. 124/70. Right percutaneous angiography was performed under local anesthesia with 200 mg. nembutal and 0.4 mg. atropine as premedication with satisfactory demonstration of the carotid circulation. Two days later a similar procedure was carried out on the left side, again under local anesthesia, with 200 mg. nembutal and 100 mg. demerol as premedication. Following a 2nd 10 cc. injection of 35 per cent diodrast, hemiplegia and aphasia developed. Within 3 hours the patient was able to move her arm and leg but her aphasia persisted until the following day.

*Case 9.* H.G., a 57-year-old male, had had previous hospital admissions for multiple cranial nerve palsies of undetermined etiology. On this admission, he exhibited a complete left 3rd and 4th cranial nerve palsy and a partial right 3rd and 4th palsy. B.P. was 145/90. Cardiac status was normal. Left open carotid angiography was done under cervical block anesthesia, with 10 mg. morphine and 0.5 mg. atropine for premedication, with demonstration of a normal cerebral carotid circulation and no sequelae. The neurological status remained unchanged and 5 months later right carotid arteriography was done by percutaneous injection under local anesthesia with 200 mg. nembutal for premedication. Following the 1st 10 cc. injection of 35 per cent diodrast, the patient suffered a left hemiparesis and aphasia, which subsided within 1 hour.

It is of interest that in both of these cases the opposite side had been injected first without complications.

(B) *Seizures.*

*Case 10.* G.S., a 62-year-old female, was admitted because of a sudden episode of unconsciousness associated with a left Jacksonian seizure followed by right-sided headaches. Lumbar puncture yielded grossly bloody CSF. Neurologic and cardiac findings were negative but her B.P. was 260/110 and renal damage was evident. Percutaneous angiography was attempted under local anesthesia, with 200 mg. nembutal and 0.4 mg. atropine for premedication, with inadequate filling. One week later right open arteriography was done under cervical block anesthesia, with 10 mg. morphine, 0.4 mg. atropine and 100 mg. seconal as premedication. Two 10 cc. injections of 35 per cent diodrast were performed. Following the 2nd injection, a transient, left-sided Jacksonian seizure occurred, associated with loss of consciousness. X-rays revealed an aneurysm in the right posterior communicating artery. Ligation of the right common carotid artery was undertaken. During trial occlusion, an immediate and complete left hemiparesis developed. Upon release, the hemiparesis cleared completely. This was repeated 3 times over several hours until finally ligation was accomplished by tantalum clip. No neurological deficit ensued and her convalescence was uneventful.

*Case 11.* W.B., a 33-year-old male, was admitted after a spontaneous subarachnoid hemorrhage which had been treated for 4 days in another hospital. Neurologic and cardiac findings were negative with the exception of nuchal rigidity. B.P. was 110/65. Left percutaneous carotid angiography was attempted under local anesthesia with 240 mg. sodium luminal as premedication. The vertebral artery was inadvertently entered, with satisfactory visualization of the vertebral circulation. The operator was unable to obtain carotid arterial filling. Three days later right percutaneous angiography was carried out under local anesthesia with 120 mg. of sodium luminal as premedication. During the 1st 10 cc. injection of 35 per cent diodrast the patient had a grand mal convulsion without other sequelae. Three days later right open carotid angiography was done, using 120 mg. of sodium luminal, 75 mg. of demerol and 0.4 mg. atropine as premedication, with 40 cc. of 35 per cent diodrast in a series of 4 injections. A right anterior cerebral aneurysm was demonstrated. There were no sequelae.

(C) *Thrombosis of Internal Carotid Artery.*

*Case 12.* C.T., a 56-year-old diabetic male, was admitted with pain in the left eye of 5 days' duration. Neurological and cardiac findings were negative except for dilatation and fixation of his left pupil. Percutaneous angiography was attempted in the left common carotid artery under local anesthesia, with 100 mg. of demerol as premedication. The internal carotid artery did not fill but external circulation was normal. Four days later open arteriography was performed and the entire internal carotid vessel was visibly and palpably thrombotic. After ligation, it was found to be filled with recent clot (Fig. 3). Paralysis of the right arm and leg gradually developed during the ensuing month.

(D) *Injury to Cervical Sympathetic Chain.*

*Case 13.* C.D., a 23-year-old female, was admitted with a spontaneous subarachnoid hemorrhage. Right percutaneous angiography was performed under sodium pentothal anesthesia with 240 mg. sodium luminal and 0.4 mg. atropine as

premedication. Five 10 cc. injections of diodrast were made and satisfactory angiograms obtained. During the course of the examination a right ptosis and myosis developed. Subsequently, a left-sided injection was done by the open technique and no complications were seen. It is thought that the ptosis and myosis were due to damage of the cervical sympathetics during the attempts to pierce the carotid artery.

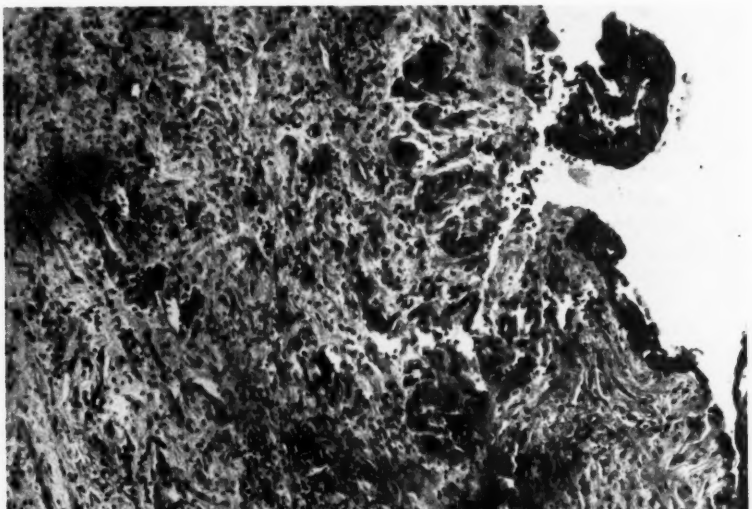

FIG. 3. *Case 12.* Photomicrograph of left internal carotid showing organizing thrombus within its lumen.

(E) *Diodrast Sensitivity.*

*Case 14.* A.B., a 32-year-old male, was admitted because of spontaneous subarachnoid hemorrhage. Left percutaneous angiography was carried out under local anesthesia with 100 mg. nembutal, 10 mg. morphine and 0.4 mg. atropine as premedication. Two 15 cc. injections of 35 per cent diodrast had been completed when a rash appeared over the left arm and clavicular region. Patient had shown a slight sensitivity on skin test to the diodrast and further attempt at angiography was discontinued. The rash was transitory and there were no other sequelae. It is of interest that this is the only patient in the entire series exhibiting sensitivity by skin test and no neurological complications followed injection of the radiopaque substance.

## DISCUSSION

A far higher proportion of complications have occurred than indicated in the literature when inclusion is made of delayed complications. From 1940 to 1946, 22 angiograms performed by one of the authors (WBS) and limited to cases of suspected aneurysm were not accompanied by any known com-

plications.* However, since the War, when angiography was extended to include all cerebral diagnostic problems regardless of age or condition, there have been nearly 10 per cent of complications. Out of 108 cases and 147 angiograms, there were 14 complications (nearly 10 per cent), of which 8 were major (5 per cent), including 3 deaths and 4 permanent paralyses, and 6 were minor (4 per cent), including 2 convulsions. The technical procedures were carried out by both the attending and resident neurological staff, totaling 9 surgeons. There does not appear to be any direct relationship between the complications and (a) open *vs.* closed technique; (b) the surgeon performing the procedure; (c) premedication; (d) rapidity of injection or quantity used, and (e) presence of hypertension. There does appear to be a direct relationship to the *selection* of cases, complications arising in those older patients having a tendency toward thromboses (Fig. 4) or in patients having impaired cerebral circulation from one cause or another (tumor and aneurysm).

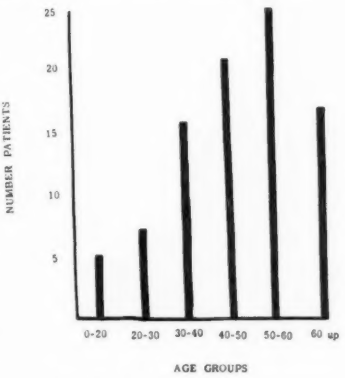


FIG. 4. Diagrammatic representation of the 91 uncomplicated cases of angiography from which this series was drawn, illustrating the large proportion of angiograms performed in the older age groups.

Vasospasm probably plays the major part in the causation of complications, although statistical proof cannot be offered from this series. Diodrast is known to cause vasospasm. Holm[9] noted the difference in caliber of cerebral vessels when injected with 35 per cent diodrast as compared to thorotrast. The delayed sequelae as reported in diodrast urography by Pendergrass, Chamberlin, Godfrey and Burdick[12] may well be due to impaired cerebral circulation. The delayed nature of many of the complications in this series suggests thrombosis following initial vasospasm or tissue anoxia. The rather extensive infarction in the pathological specimens so far obtainable confirms this impression. Inasmuch as only 1 patient in the entire series showed a skin reaction, it seems unlikely that organ sensitivity to diodrast is a cause of complications. The rationale of both treatment and prophylaxis in the complications of angiography would appear to lie in the relief of vasospasm. Vasodilators, especially papaverine, novocain infiltration of the carotid sheath, unilateral or bilateral block of the stellate ganglion, as well as its removal or isolation have all been recommended.

The following prophylactic measures are recommended by the authors for use in those cases in which there are signs of defective cerebral circulation as indicated by age, history or neurologic deficits:

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* Experiences in angiography. Presented before The American Academy of Neurological Surgery, Colorado Springs, Colorado, October 9, 1947.

1. Pre- and postoperative papaverine administration for 1 and 2 days respectively.

2. Preoperative intravenous sodium luminal, gr. IV.

3. A general anesthetic and/or a short delay between injections have been considered on theoretical grounds.

4. In those cases in which a thrombosis develops, repeated stellate novocain blocks on alternating sides at intervals of 4 to 6 hours.

## CONCLUSIONS

1. Fourteen complications of cerebral angiography are reported. These include 3 fatalities, 4 cases of hemiplegia with permanent residual deficits, 2 cases of transitory hemiplegia, 2 cases of convulsions, 1 case of carotid artery thrombosis, 1 case of injury to the cervical sympathetic chain, and 1 case of diodrast skin sensitivity.

2. The technical details of proficiency, quantity, methods and medication used in the performance of arteriography apparently are not important factors in the etiology of complications.

3. The selection of cases is important with the older age group, especially those having thrombotic tendencies or other evidence of impaired cerebral circulation exhibiting the greatest liability.

4. The delayed nature of most of the serious complications of angiography is stressed and the probability of cerebral thrombosis secondary to irritative vasospasm is suggested as the pathologic etiology.

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## REFERENCES

1. Bull, J. W. D. Cerebral angiography. *Postgrad. med. J.*, 1950, *26:* 157–165.
2. Chusid, J. G., Robinson, F., and Margules-Lavergne, M. P. Transient hemiplegia associated with cerebral angiography (diodrast). *J. Neurosurg.*, 1949, *6:* 466–474.
3. Dyke, C. G. Discussion of Gross, S. W.[7] *Arch. Neurol. Psychiat., Chicago*, 1940, *44:* 219–220.
4. Ekström, G., and Lindgren, A. G. H. Gehirnschädigungen nach cerebraler Arteriographie mit Thorotrast. *Zbl. Neurochir.*, 1938, *3:* 227–248.
5. Engeset, A. Cerebral angiography with perabrodil (carotis angiography). *Acta radiol. Stockh.* 1944, suppl. 56, 207 pp.
6. Gross, S. W. Cerebral arteriography in the dog and in man with a rapidly excreted organic iodide. *Proc. Soc. exp. Biol. N. Y.*, 1939, *42:* 258–259.
7. Gross, S. W. Cerebral arteriography by means of a rapidly excreted organic iodide. *Arch. Neurol. Psychiat., Chicago*, 1940, *44:* 217–219.
8. Gross, S. W. Cerebral arteriography. Its place in neurologic diagnosis. *Arch. Neurol. Psychiat., Chicago*, 1941, *46:* 704–714.
9. Holm, O. F. Cinematography in cerebral angiography. *Acta radiol., Stockh.*, 1944, *25:* 163–173.
10. Moniz, E. L'angiographie cérébrale. Ses applications et résultats en anatomie, physiologie et clinique. *Paris: Masson & Cie*, 1934, 327 pp.
11. Northfield, D. W. C., and Russell, D. S. The fate of thorium dioxide (thorotrast) in cerebral arteriography. *Lancet*, 1937, *1:* 377–381.
12. Pendergrass, E. P., Chamberlin, G. W., Godfrey, E. W., and Burdick, E. D. A survey of deaths and unfavorable sequelae following the administration of contrast media. *Amer. J. Roentgenol.*, 1942, *48:* 741–762.
13. Torkildsen, A. Carotid angiography with special reference to the diagnosis of cerebral gliomas. *Acta psychiat., Kbh.*, 1949, suppl. 55, 168 pp.

# COMPLICATIONS OF LIGATION OF THE INTERNAL CAROTID ARTERY*

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LIGATION of carotid vessels has probably been carried out from the earliest times in the course of treatment of wounds of the neck. Ever since John Abernethy[1] first adequately described such a ligation and the hemiplegia and later death which ensued, the serious risks of the procedure have been recognized. In pre-Listerian days the cerebral complications were often over-shadowed by suppuration of the cervical wound and resultant secondary hemorrhage. Since the introduction of asepsis into surgery the importance of the cerebral complications has been fully recognized.

Norris[6] in 1847 reported 149 cases of carotid ligation with death in 36

TABLE 1

*Lesions for which 40 ligations of the internal carotid artery were performed*

| | Non-fistulous Aneurysm | Arteriovenous Fistula | Miscellaneous | Total |
|---|---|---|---|---|
| No complications | 19 | 2 | 3 | 24 |
| Temporary complications | 2 | 0 | 0 | 2 |
| Permanent complications | 6 | 0 | 1 | 7 |
| Death | 6 | 1 | 0 | 7 |
| Total | 33 | 3 | 4 | 40 |

per cent and permanent sequelae in another 21 per cent. According to Schorstein,[9] Trotter in 1924 reported 60 cases with 13 per cent deaths and 13 per cent of complications. This author was the first to carry out carotid ligation for non-fistulous aneurysm. The majority of the reports in the literature parallel more or less closely the above figures with the exception of that of Dandy[2] who in 1942 reported 88 cases with a mortality of only 4.5 per cent and complications in only 5.6 per cent. Even the recent report of Poppen[7] does not significantly excel Dandy's[2] results. Dandy[3] stressed the use of the Matas test preoperatively (percutaneous compression of the carotid for 10 minutes or longer) and when this produced any neurologic symptoms he carried out a partial ligation initially. A week or two later complete occlusion of the vessel was carried out. In the present series

* Presented at the meeting of the Harvey Cushing Society, Colorado Springs, Colorado, April 16, 1950.

internal carotid ligation has been carried out in 40 patients (Table 1). In 33 of these (83 per cent) the ligation was performed because of the proven or suspected presence of non-fistulous intracranial aneurysm. All but one of the ligations (this exception will be referred to later) were carried out under local anesthesia after preliminary occlusion of the vessel for 20–30 minutes without the development of any untoward symptoms. They were all carried out in one stage with the exception of one patient who had a partial occlusion with a tantalum clip. At a later stage in this patient, the internal carotid artery was divided between ligatures. With this exception all of the vessels were ligated in continuity.

As shown in Table 2, death occurred in 7 cases (17 per cent). Three of these deaths were in patients over 50 years of age (total 5). The mortality for patients under 50 years of age was 11 per cent, a figure still twice that

TABLE 2

*Incidence of death and complications in patients over and under 50 years of age in whom the internal carotid artery was ligated*

| | Age | | Total |
|---|---|---|---|
| | Over 50 | Under 50 | |
| No complications | 2 | 22 | 24 |
| Temporary complications | 0 | 2 | 2 |
| Permanent complications | 0 | 7 | 7 |
| Death | 3 | 4 | 7 |
| Total | 5 | 35 | 40 |

reported by Dandy.[2] Necropsy was carried out in 5 of these 7 cases. In 2 patients a thrombus had propagated from a completely thrombosed aneurysm so as to occlude the anterior and middle cerebral arteries on the ligated side. Both of these aneurysms were on the supraclinoid portion of the internal carotid. In 1 patient a thrombus had propagated from the site of the ligature in the neck into the intracranial portion of the carotid and occluded the middle and anterior cerebral vessels. In 1 patient on whom permission for necropsy was not obtained the presence of a similar propagating thrombus was established before death:

This 74-year-old woman, the oldest patient in the series, had ligation of the right internal carotid artery because of progressive proptosis due to a traumatic arteriovenous aneurysm of the cavernous sinus. She had tolerated 30 mins. of occlusion of the vessel after surgical exposure under local anesthesia before ligation was carried out. Three hours later left hemiplegia developed and shortly thereafter the patient became comatose. She was taken to the operating room and the artery was exposed. Aspiration of the vessel distal to the ligature yielded no blood and when the vessel was opened it was found to be filled with a fresh thrombus. Efforts to extricate the thrombus were unsuccessful and the patient died a short while later. Permission for

necropsy was not obtained but it was thought that the thrombus had propagated up into the principal branches of the right internal carotid artery.

One patient died of a cerebral hemorrhage apparently unrelated to her aneurysm:

She was a 53-year-old hypertensive patient who had a ligation of the left internal carotid artery because of an aneurysm of its cavernous portion. Twelve hours later, following a sharp rise in B.P. to 210/120, right hemiplegia and aphasia developed. This was thought to be due to thrombosis of the left middle cerebral artery. Procaine block of the left stellate ganglion did not produce any improvement. Death occurred about 60 hours after the ligation. At necropsy there was no evidence of recent hemorrhage from the aneurysm of the cavernous portion of the internal carotid. There was a walnut-sized hematoma in the left frontal lobe with rupture into the ventricle. Recent fresh hemorrhage had occurred in addition to older hemorrhage. There was no evidence of thrombosis of any of the major cerebral arteries.

This patient apparently had a subcortical hemorrhage of hypertensive origin into the left frontal lobe. This had ruptured into the ventricle. The finding of blood in the cerebrospinal fluid and of left carotid aneurysm by angiography led to the assumption that we were dealing with subarachnoid hemorrhage from a leaking aneurysm. Additional hemorrhage occurred after the carotid ligation. The cause of this is not clear but it may have been due to a reflex rise in blood pressure in a hypertensive patient with vasomotor instability. Death was due to intracerebral hemorrhage not directly related to the carotid aneurysm or to the internal carotid ligation 60 hours before.

Another patient died of pneumococcic meningitis secondary to lobar pneumonia. This was an early case treated before sulfonamides or antibiotics were in use. The death occurred 9 days after the ligation and does not seem a direct result of that procedure as there was no hemiparesis and no evidence was found at necropsy of thrombosis or embolism. However, it has been included in the operative deaths.

Neurologic complications occurred in 9 patients (Tables 3 and 4). All of these had their onset within 12 hours after ligation with 1 exception:

This 43-year-old man had an aneurysm of the left posterior communicating artery (Fig. 1). Left frontoparietal osteoplastic craniotomy was carried out but because of acute swelling of the cerebral hemisphere the aneurysm could not be exposed. Six weeks later the left internal carotid artery was ligated. There were no untoward symptoms for 48 hours. Then in the presence of a physician he leaned out of bed to pick up a paper which had fallen to the floor. He immediately became aphasic and within 15 minutes right hemiplegia developed. This has been permanent to the present time (18 months). It was felt that an embolus from a thrombus proximal to the ligature had lodged in the left middle cerebral artery.

Two patients had a temporary hemiparesis which disappeared within 48 hours. These patients were thought to have had vasospasm of cortical vessels without thrombosis.

A 37-year-old man had ligation of the right internal carotid artery under general anesthesia in the course of the resection of a carotid body tumor. When he regained consciousness he complained of visual disturbance. Examination revealed left homonymous hemianopsia which has persisted (15 months). This was thought to be due to an inadequate circle of Willis. The posterior cerebral artery on the right apparently received its principal supply from the internal carotid through the right posterior communicating artery with an inadequate supply from the basilar. After internal carotid

TABLE 3

*Clinical manifestations in 9 patients with neurologic complication after internal carotid ligation*

| Complications (Clinical Manifestations) | |
|---|---|
| Temporary hemiparesis | 2 |
| Permanent homonymous hemianopsia | 1 |
| Permanent monoparesis (leg) | 1 |
| Permanent monoparesis (arm) with astereognosis | 1 |
| Permanent hemiparesis | 2 |
| Permanent hemiplegia | 1 |
| Permanent hemiplegia and aphasia | 1 |

TABLE 4

*The type of vascular lesion and the time of onset in 9 patients with neurologic complication after internal carotid ligation*

| Complications (Type of Lesion) | |
|---|---|
| Inadequate circulation | 1 |
| Vasospasm | 2 |
| Thrombosis | 5 |
| Embolism | 1 |
| **Time of Onset After Ligation** | |
| 1–12 hours | 8 |
| 48 hours | 1 |

ligation on the right, the entire right cerebral circulation had to be supplied through the anterior communicating artery. This proved adequate for the anterior and middle cerebral vessels but inadequate for the posterior cerebral, probably because of the additional shunt through a vessel of small caliber (the posterior communicating). The lack of angiographic studies in this patient makes the above explanation entirely theoretical.

The remaining complications (5 patients) were thought to be due to cortical thrombosis. This was especially true of the 2 cases in which monoparesis was the only permanent sequel. In the other 3 cases the involvement of both arm and leg indicates either more extensive cortical thrombosis or

occlusion of one of the principal branches of the middle cerebral artery. It is possible that a propagating thrombosis of the internal carotid artery above the ligature eventually involved the middle cerebral artery in some of these patients. The lowered systolic and pulse pressure on the ligated side may induce thrombosis within the aneurysm (in cases of aneurysm) and such a thrombus may propagate into a principal cerebral artery. Sweet, Sarnoff,

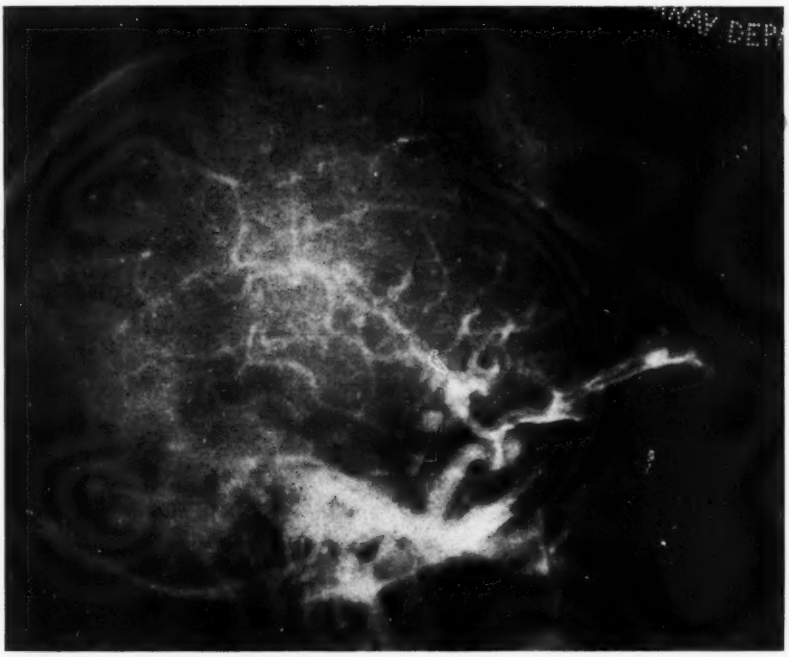

FIG. 1. Lateral carotid angiogram of aneurysm of left posterior communicating artery. Treated by internal carotid ligation.

and Bakay[12] have reported such a case and, as previously mentioned, 2 of our deaths were due to this.

As Dandy[2] and Rogers[8] have pointed out, and as has been indicated above, the deaths or neurologic complications after internal carotid ligation can be divided into those that occur early (within a few hours) and those with a later onset. The early occurrence is due to an inadequate circulation, the later to thrombosis, or to emboli from a thrombus in the internal carotid. Thrombosis may propagate distally from the site of the ligature in the neck or from a thrombus in the aneurysm. In either case it may occlude by its propagation the middle and anterior cerebral arteries and where the posterior communicating is large the posterior cerebral as well. Thrombosis

may also be primary in a peripheral cortical vessel. Such a thrombus may propagate proximally in the vessel, occluding successively more cortical branches and finally a main arterial trunk. As has been shown, all of these causes have operated in producing the deaths and neurologic complications in the present series.

The recognition of inadequacy of the collateral circulation of the circle or heptagon of Willis depended in the past on the Matas test (percutaneous compression of the carotid) or occlusion of the carotid after surgical exposure under local anesthesia. Although only 1 patient in this series had carotid ligation without preliminary occlusion for 20–30 minutes after surgical exposure under local anesthesia (that patient, already referred to, developed permanent homonymous hemianopsia), a disturbing number of deaths and complications occurred. The Matas test carried out pre-operatively is of positive value in that if percutaneous compression of the carotid produces neurological signs it is clear that the patient will not tolerate complete surgical occlusion. However, the technical difficulty of producing prolonged complete occlusion of the carotid by percutaneous compression is so great that failure to produce neurologic signs by such compression cannot be safely taken to indicate that the patient will tolerate complete surgical occlusion.

Because of the many sequelae that occurred in spite of the use of preliminary occlusion of the carotid artery some surgeons have advised ligation of the common carotid instead of the internal carotid artery. As a matter of fact, in many of the reports dealing with carotid ligation it is not clear whether the common or internal carotid artery was occluded. The advocates of common carotid ligation have claimed that reflux flow of blood from the external into the internal carotid vessel through the anastomoses of the branches of the external carotid with their fellows of the opposite side would provide the necessary additional flow to the cerebral vessels on the ligated side in case of an inadequate circle of Willis. Rogers[8] thought that the increased pressure in the carotid sinus following internal carotid ligation would lower blood pressure, thus further endangering the cerebral ligation. On the other hand a number of surgeons have considered that ligation of the common carotid offered no advantages over internal carotid ligation as far as initial safety was concerned and that it carried the theoretical disadvantage of later increase in pressure on the ligated side because of development of the collateral circulation of the external carotid. Some advocates of common carotid ligation advise the later occlusion of the internal carotid.

Dandy[3] was perhaps the leading advocate of partial occlusion of the internal carotid whenever preliminary compression of the carotid indicated an inadequate collateral circulation. Seven to 10 days later he carried out complete occlusion. It will be recalled that only very recently has Dandy's low rate of deaths and complications been equalled.

Electroencephalographic studies of the ipsilateral hemisphere during

percutaneous or surgical occlusion of the internal carotid artery have been used by Elvidge and Feindel[4] and others to determine if the cerebral hemisphere is receiving an adequate blood supply. Because of the sensitivity of the cerebral cortex to anoxia this would appear to be an accurate method for evaluation of the collateral circulation during temporary occlusion. However, in a footnote, they refer to a patient in whom hemiplegia developed

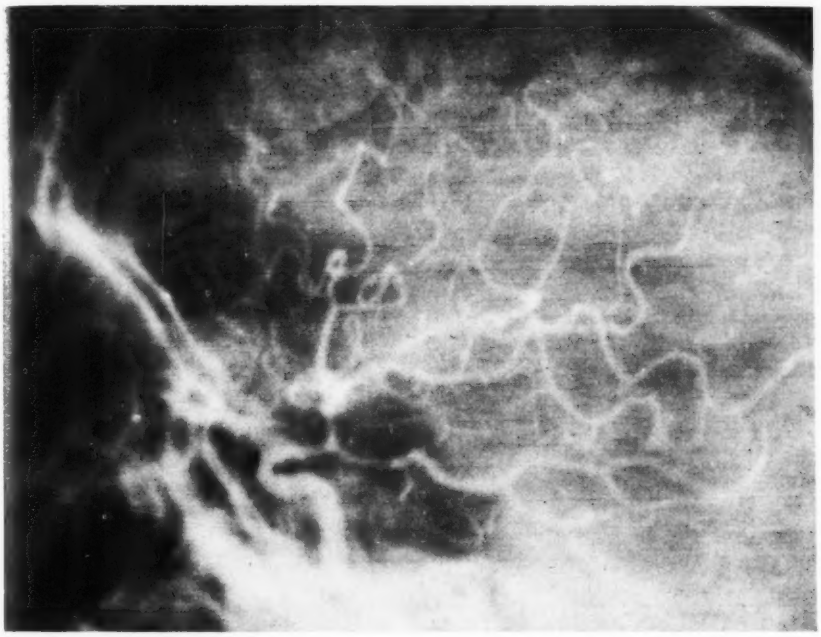

FIG. 2. Right lateral carotid angiogram. There is excellent filling of the posterior cerebral artery but not of the anterior cerebral.

10 hours after a 2nd-stage carotid ligation although EEG studies had previously shown no evidence that would predict this. Another of their patients had a relatively normal EEG during the development of a hemiplegia following carotid ligation.

The preoperative use of bilateral carotid angiography in estimating the circle of Willis has proven of great value to the surgeon contemplating a surgical attack on an intracranial aneurysm. While at times there may be technical difficulties with this procedure it should be carried out, if possible, in all cases. The importance of preoperative visualization of the aneurysm was at once apparent to neurologic surgeons. They have been slower to recognize the equal importance of visualization of the circle of Willis before evaluating a patient with intracranial aneurysm for surgery. It is important

not only to demonstrate an adequate circulation through the circle of Will s but also to evaluate the location and size of the aneurysm as the latter ma v be a factor at times in obstruction of the circulation. The following patien t illustrates the value of bilateral carotid angiography in evaluating the cerebral circulation.

This 48-year-old man had 2 successive episodes of subarachnoid hemorrhage a

FIG. 3. Right anteroposterior carotid angiogram. Unsatisfactory filling of anterior cerebral artery in spite of percutaneous compression of the left carotid at the time of injection. Same case as Fig. 2.

week apart. Ten days later right carotid angiography was carried out. Figs. 2 and 3 show lateral and anteroposterior roentgenograms taken during this procedure. There is good filling of the posterior cerebral artery but the anterior cerebral artery did not fill satisfactorily, although percutaneous compression of the left carotid vessels was carried out during the injection for the anteroposterior films. Three days later left carotid angiography was carried out. Figs. 4 and 5 show lateral and anteroposterior roentgenograms made at that time. There was no filling of the posterior cerebral artery in these films but filling of both anterior cerebral arteries was demonstrated. The large aneurysm on the anterior cerebral artery appeared technically suitable for trapping between clips but in view of the arteriograms (Fig. 6) it was

felt that the patient would not tolerate occlusion of the left anterior cerebral artery and that internal carotid ligation would surely be fatal. Five days later the patient expired following a third episode of subarachnoid hemorrhage.

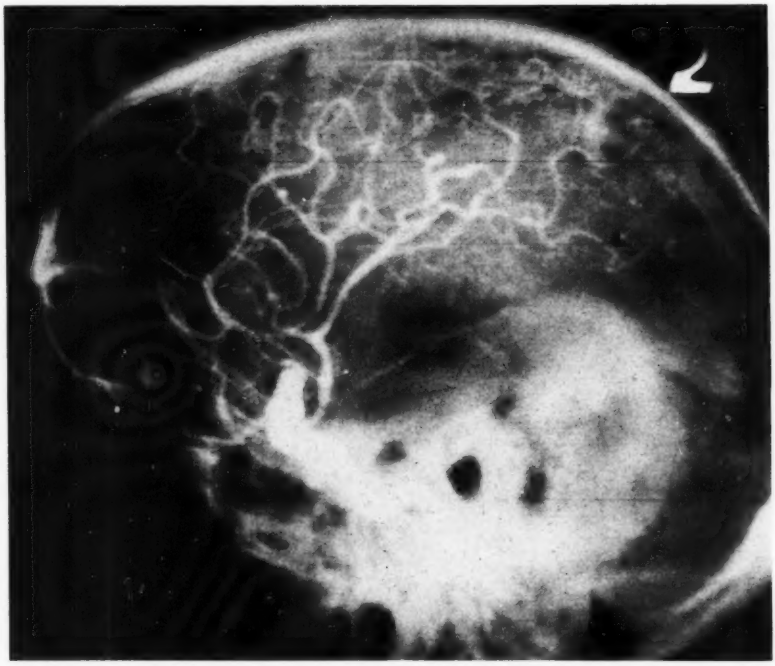

FIG. 4. Left lateral carotid angiogram. There is a large aneurysm of the anterior cerebral artery. The posterior cerebral artery is not filled. Same case as Figs. 2 and 3.

Fig. 7 is a photograph of the circle of Willis removed after the brain was removed at necropsy. The stump of the aneurysm is shown as well as the anomalous character of the circle of Willis. The right anterior cerebral artery was patent but small. It is doubtful if it could have supported the anterior cerebral circulation bilaterally and it is certain that it could not have supported the left carotid circulation if carotid ligation had been carried out, as the left posterior communicating artery was rudimentary.

The apparatus devised by Sweet and his co-workers[11,12] for recording intracarotid pressure has not only made possible their basic studies on this problem but is also another valuable method of determining the status of the collateral circulation. They have shown that after internal carotid occlusion the systolic pressure distal to the occlusion falls to an average of approximately 50 per cent and the pulse pressure to an average of approximately 30 per cent of the initial levels. If there is a fall of 70 per cent or

more in the systolic pressure they consider that the collateral circulation is dangerously poor. Obviously in such a case the use of this method would permit the adjustment of partial occlusion of the internal carotid to allow a satisfactory pressure distal to the occlusion.

In their studies occlusion of the external carotid artery in addition to occlusion of the common carotid produced no significant effect on the

FIG. 5. Left anteroposterior carotid angiogram. The location of the aneurysm of the anterior cerebral artery is well shown. Same case as Figs. 2, 3, and 4.

internal carotid pressure. In an occasional instance it did and they recently concluded that, in the absence of adequate pressure studies, common carotid ligation is safer as a preliminary measure than internal carotid ligation. The latter may be carried out at a later date.

They also studied the effect of percutaneous compression of the opposite carotid on the pressure in the ipsilateral occluded internal carotid. The result of this depends on the efficacy of the anterior communicating and the posterior communicating arteries. They discovered that satisfactory occlusion of the carotid by percutaneous compression is difficult to achieve. I bilateral ligation of the internal carotid arteries is indicated in the treatmen

of an aneurysm, pressure studies of this type seem to be the only way in which the possibility of carrying out such a procedure safely can be determined. It should be emphasized that this procedure will be rarely feasible as the posterior communicating arteries are seldom large enough to carry the burden of the cerebral circulation.

It seems that at the present time we have methods of determining preoperatively the adequacy of the collateral circulation through the circle of Willis before undertaking internal carotid ligation. The problem remains

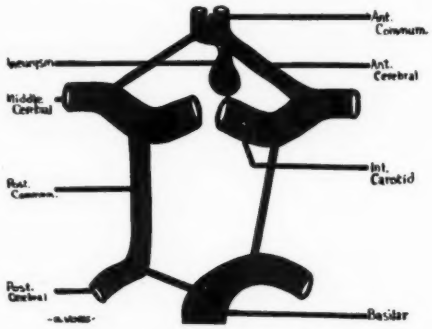


FIG. 6. Hypothetical diagram of circle of Willis with aneurysm of left anterior cerebral artery constructed from evidence of angiograms in Figs. 2, 3, 4, and 5.

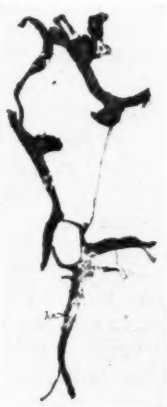

FIG. 7

FIG. 7. Photograph of arteries of circle of Willis removed after the brain had been hardened in formalin. The stump remains of the aneurysm of the left anterior cerebral artery. Same case as Figs. 2, 3, 4, and 5.

of preventing thrombosis in cerebral blood vessels, propagating thrombosis in the internal carotid artery or the aneurysm, or embolism from thrombosis distal to the ligature. Rogers,[8] especially impressed with the dangers of embolism or propagating thrombosis, advocated the Celsian operation of ligation and division of the common carotid artery rather than ligation in continuity. He pointed out that with division between ligatures recanalization cannot occur, the perivascular sympathetic fibers are divided and that embolism from a thrombus distal to the ligature is less likely to occur. When he ligated the internal carotid artery he resected it as near to the floor of the skull as possible as he felt the blind pouch of the internal carotid artery after ligation favored propagating thrombus.

However, division between ligatures precludes the possibility of removal of a ligature if neurologic signs develop after ligation. The experience of Love,[5] Dandy[3] and others indicates that such removal may result in improvement although of course it will not do so in cases of propagating thrombus or where major cerebral vessels have become occluded. However, it

seems best to ligate in continuity so that the ligature may be removed if complications develop. Before this is done the artery distal to the ligature should be aspirated so that one is certain that it is not occluded by thrombus.

The use of sympathetic block on the side of ligation and of anticoagulant therapy seem the most promising methods of avoiding late complications. At the time of ligation the cervical sympathetic chain may be blocked with procaine and these procaine blocks may be repeated at 12-hour intervals for the first day or two. In the case of active bleeding from an aneurysm anticoagulant therapy is of course contraindicated but in other cases this therapy should be started a few hours after ligation and maintained for 3 or 4 days. The use of peripheral vasodilators such as histamine or tetraethyl ammonium chloride is probably contra-indicated because of their tendency to produce drop in blood pressure thus favoring further vascular stasis and thrombosis. Shenkin *et al.*[10] have shown that adequate doses (1 to 2 grains) of papaverine do increase the cerebral blood flow. Their results indicate this drug should have value in the postoperative management of these patients.

## SUMMARY

Ligation of the internal carotid artery carries a high risk in patients over 50 years of age and should not be undertaken unless as an emergency. Even in younger patients careful preoperative study with bilateral carotid angiography is desirable. Ligation should be done under local anesthesia with preliminary occlusion of the vessel for 20 to 30 minutes. If possible the intra-carotid pressure above the occlusion should be measured. If this is reduced to 30 per cent or less of the initial pressure or if the patient shows neurological signs during the test period of occlusion only a partial ligation of the artery should be made initially. Later it may be completely occluded. In the absence of arteriography or intra-carotid pressure studies, preliminary ligation of the common carotid may offer some additional safety. If this is done the internal carotid may be ligated a week or two later.

After ligation of the internal carotid repeated procaine blocks of the cervical sympathetic trunk on the side of the ligation should be made. Anticoagulant therapy should be maintained for 3 or 4 days. Adequate doses of papaverine may be administered. The patient should be kept at bed rest for 7 to 10 days.

## REFERENCES

1. Abernethy, J. Surgical observations on injuries of the head; and on miscellaneous subjects. *Philadelphia: T. Dobson*, 1811, 162 pp.
2. Dandy, W. E. Results following ligation of the internal carotid artery. *Arch. Surg., Chicago*, 1942, *45:* 521–533.
3. Dandy, W. E. Intracranial arterial aneurysms. *Ithaca, N.Y.: Comstock Publishing Co. Inc.*, 1944, viii, 147 pp.
4. Elvidge, A. R., and Feindel, W. H. Surgical treatment of aneurysm of the anterior cerebral and of the anterior communicating arteries diagnosed by angiography and electroencephalography. *J. Neurosurg.*, 1950, *7:* 13–32.

5. Love, J. G. Restoration of circulation after removal of ligature from internal carotid artery. *Proc. Mayo. Clin.*, 1944, *19:* 375–376.
6. Norris, G. W. Statistics of the mortality following the operation of tying the carotid arteries and arteria innominata. *Amer. J. med. Sci.*, 1847, *14:* 13–40.
7. Poppen, J. L. Specific treatment of intracranial aneurysms. Experiences with 143 surgically treated patients. *J. Neurosurg.*, 1951, *8:* 75–102.
8. Rogers, L. Ligature of arteries, with particular reference to carotid occlusion and the circle of Willis. *Brit. J. Surg.*, 1947, *35:* 43–50.
9. Schorstein, J. Carotid ligation in saccular intracranial aneurysms. *Brit. J. Surg.*, 1940, *28:* 50–70.
10. Shenkin, H. A., Cabieses, F., van den Noordt, G., Sayers, P., and Copperman, R. The hemodynamic effect of unilateral carotid ligation on the cerebral circulation of man. *J. Neurosurg.*, 1951, *8:* 38–45.
11. Sweet, W. H., and Bennett, H. S. Changes in internal carotid pressure during carotid and jugular occlusion and their clinical significance. *J. Neurosurg.*, 1948, *5:* 178–195.
12. Sweet, W. H., Sarnoff, S. J., and Bakay, L. A clinical method for recording internal carotid pressure. Significance of changes during carotid occlusion. *Surg. Gynec. Obstet.*, 1950, *90:* 327–334.

# CASE REPORT

## MULTIPLE CEREBRAL ANEURYSM

### REPORT OF A CASE

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(Received for publication July 10, 1950)

Because of the serious influence of multiplicity of cerebral aneurysm upon the prognosis for such lesions, we believe it worth while to report the following successfully treated case.

D.H. was a 30-year-old white male admitted to the University Hospital on Dec. 21, 1949. Two months previously he had had severe headache lasting 2 days, accompanied by stiffness of the neck. Three weeks before admission he slipped and fell and within a half hour, while lifting a heavy tool box, he had sudden onset of severe headache in the occipital region associated with marked stiffness of and pain in the neck. Lumbar puncture revealed xanthochromic fluid and fresh red blood cells. He was then referred for treatment.

*Examination.* There were no abnormal findings. B.P. was 126/70. In the absence of localizing signs, percutaneous angiography with 35 per cent diodrast was elected and demonstrated an aneurysm arising from the base of the middle cerebral artery on the right side (Fig. 1).

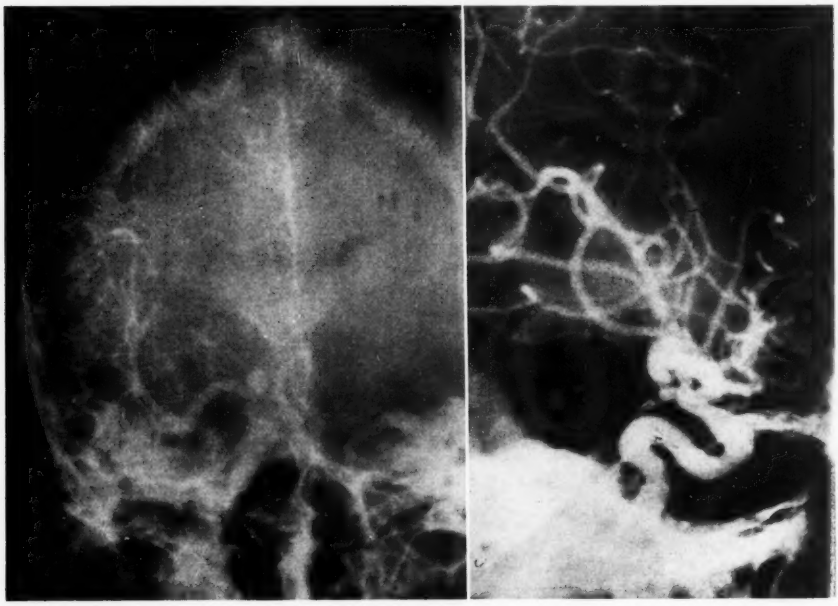

FIG. 1. AP and lateral angiogram demonstrating saccular aneurysm arising from right middle cerebral artery just lateral to the bifurcation.

*Operation.* A pituitary type flap was turned down on the right on Dec. 23, 1949. Following arachnoidal dissection of the optic nerve and the carotid artery, the cortex over the adjacent temporal lobe was seen to be pigmented and was adherent to the artery. This region was first by-passed in the approach to the middle cerebral artery. The aneurysm was found on this structure as demonstrated in the arteriogram and was obliterated with silver clips and gel-foam tampons.

Absence of evidence for old or recent hemorrhage about this lesion led to more careful inspection of the pathology suggested by blood pigment at the tip of the temporal lobe adjacent to the carotid artery. The arachnoid was further carefully dissected from this vessel and a small mulberry-sized aneurysm was demonstrated on the lateral surface of the carotid artery just below the bifurcation (Fig. 2). This was the source of the subarachnoid bleeding. The dome of the sac was thrombosed and adherent to the cortex. The lesion was isolated

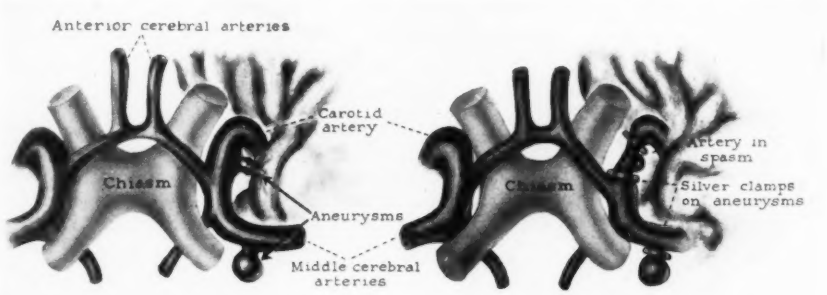


FIG. 2. Diagrammatic reconstruction showing the relationship of the two aneurysms to the circle of Willis (left) and the manner in which they were isolated (right).

by silver clips proximal and distal to it on the carotid artery. Application of the clips to the carotid artery was facilitated as this structure went into spasm when grasped and held by the bayonet forceps.

As a result of this (trapping) procedure the only collateral circulation of consequence available to the right hemisphere was through the anterior communicating artery.

*Postoperative Course.* There was a mild hemiparesis on the left which progressed to a hemiplegia in 72 hours. Stellate block was done within a few minutes following onset of the hemiplegia and within 15 minutes the patient was moving the previously paralyzed leg and arm. Vasodilator drugs were instituted and no further profound neurologic difficulties ensued. An adynamic pneumothorax of 1750 cc. of air developed as a complication of the block; however, the lung was re-expanded without further incident.

The patient was given physiotherapy consisting of active and passive exercises and massage to the left arm and leg during his remaining 2 weeks in the hospital. At the time of discharge he had a minimal left hemiparesis. One month later his signs were practically nonexistent and 4 months postoperatively he returned to his occupation as a carpenter.

## NOTICES

### AMERICAN BOARD OF NEUROLOGICAL SURGERY

The following specialists were certified at a meeting of the American Board of Neurological Surgery in New Haven, Connecticut, in October 1950.

BRADY, JOSEPH A. 2119 Spruce St., Philadelphia, Pa.
CHENEY, ROGER H. 121 Chestnut St., Springfield, Mass.
KEEDY, CHRISTIAN 1001 DuPont Bldg., Miami 32, Fla.
KING, ARTHUR B. Guthrie Clinic, Sayre, Pa.
MARKLEY, GEORGE M. 121 State St., Harrisburg, Pa.
NULSEN, FRANK E. 3400 Spruce St., Philadelphia 4, Pa.
SELVERSTONE, BERTRAM Massachusetts General Hospital, Boston 14, Mass.
SILBERMANN, SALO J. 179 Allyn St., Hartford, Conn.
SOMBERG, HAROLD M. 31 Lincoln Park, Newark 5, N. J.
SPITZ, EUGENE B. 1740 Bainbridge St., Philadelphia 46, Pa.
STRULLY, KENNETH J. 20 Fifth Ave., New York 11, N. Y.
TRUPP, MASON 442 W. Lafayette St., Tampa 6, Fla.
WALLMAN, LESTER J. Mary Fletcher Hospital, Burlington, Vt.
WELCH, WILLIAM K. Henry Ford Hospital, Detroit 2, Mich.
WHITELEY, WILLIAM H., III Jefferson Hospital, Philadelphia, Pa.
WILLIAMS, JONATHAN M. 2014 R St., N.W., Washington 9, D. C.

### AMERICAN ACADEMY OF NEUROLOGY

The next meeting of the American Academy of Neurology is scheduled for April 11 to 13, 1951, at the Cavalier Hotel, Virginia Beach, Virginia. It will be preceded by a two-day course in neuropathology, and will be followed by the 1951 meeting of the American League Against Epilepsy.

### HARVEY CUSHING SOCIETY

The 19th annual meeting of the Harvey Cushing Society for members and invited guests will be held at the Hollywood Beach Hotel, Hollywood, Florida, April 26, 27 and 28, 1951.

### NATIONAL PARAPLEGIA FOUNDATION

The National Paraplegia Foundation announces the continuation of a limited number of fellowships for research in spinal cord disease and trauma. These fellowships carry a minimum stipend of $3000 per year and may be awarded to any candidate who has demonstrated a capacity for medical research and has outlined a program of meritorious study. The fellowships will be awarded by the Medical Advisory Committee and are open for award for the academic year 1951–1952. Application forms may be obtained from Dr. L. W. Freeman, Chairman, Medical Advisory Committee, National Paraplegia Foundation, 1040 W. Michigan St., Indianapolis 7, Ind., and should be submitted to him not later than June 1, 1951.

# CHARLES HARRISON FRAZIER

## TANGIBLES AND INTANGIBLES*

FRANCIS C. GRANT, M.D.†
*Philadelphia, Pennsylvania*

(Received for publication May 19, 1950)

THE RECONSTRUCTION of a personality fifteen years after his death is difficult. If the individual in whom one is interested has left few or no personal records that can be drawn upon, the tendency is either towards idealization or the reverse. Some of you have known Dr. Frazier, few longer than I have, but none of you more intimately, except possibly Munro, Gardner, and Watts. And knowing Dr. Frazier as I did, I am sure that he would have wished me to draw as accurate a picture of him as I can, both favorable and unfavorable. His most outstanding characteristic was a very keen sense of justice and a demand for the whole truth.

When I was about ten years of age, in the summer in Maine sailing and boathandling were my delight. My father was a grand person on anything that sailed and I was broken to the water at a very early age. Small boat racing was one of the amusements indulged in at that time. A dozen of us youngsters who knew the jib from the mainsail used to be put in a crew pool and issued to racers who did not have a regular crew. I usually raced with my father, but when he had guests or when I was in disgrace for any reason, he wouldn't take me and threw me into the pool. And so I, rather glumly, was assigned to race on a boat I knew was fast, but I wasn't sure who was going to sail her. So I rowed out and saw a slim trig man with a little moustache and the most piercing pair of blue eyes I can remember. He looked at me and welcomed me with a perfectly charming smile. He drove us hard all through the race, knew his business thoroughly, sat on my father's stern during a spinnaker run to the finish, and when my old man made a remark or two about what would happen if we luffed him again, Charlie Frazier replied in kind and put my old man in his place. I learned two or three new words I had never heard before and we wound up by beating my father by about three quarters of a length.

Naturally, Dr. Frazier was my man. He had outsailed and outtalked my own father. That night at dinner when my mother heard of it she said, "I am glad he won, he is going to marry Mary Gardner," Now Mary was one of my idols. She was the oldest, by four years, of a family of six who lived on a lovely point of land which was ideal for cops and robbers. Her four younger brothers and sisters and others of us were turned over to Mary to look out for. She was a lovely person. When I knew she was Charlie Frazier's girl my admiration for him was complete. I raced with him twice more that

* Read at the meeting of the Society of Neurological Surgeons, Chicago, Illinois, March 17–18, 1950.
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summer, saw him in Maine once or twice in the meantime, but my next direct contact was fifteen years later in the Medical School. His service was my first experience as an intern in 1919. He was stationed at Cape May at Base Hospital No. 11, coming up to Philadelphia twice a week to operate. The first patient I had with him was a fifteen-year-old boy with a presumed pituitary tumor. He told me to have the youngster ready for a transphenoidal hypophysectomy. That name was completely strange to me nor could I find anything about it in the surgical textbooks available. So to be on the safe side I shaved the boy's head, eyebrows and all. Dr. Frazier came back three days later and looked at the boy very puzzled. He said, "The family have decided against operation. What have you done to him?" I said, "It's his eyebrows." "My goodness!" is what I'll say he said for this company, "Don't you know that they will probably never grow back?" I didn't, and seeing the boy three months later, they hadn't; and they didn't, until he died six months later. The family was so angry about it they nearly sued Dr. Frazier for malpractice because they said he had changed their son's appearance completely.

Charles Harrison Frazier was born in Philadelphia on April 19, 1870. His father, W. W. Frazier, had served with honor as captain in the Sixth Pennsylvania Cavalry during the War of the Rebellion. After that war he had taken a prominent part in the social and business life of his city. His mother, Harriet Morgan Harrison, came of a family long prominent in civic affairs and closely connected in their interests with the University of Pennsylvania.

After graduating from the Episcopal Academy in Philadelphia in 1886 and receiving his A. B. degree from the University of Pennsylvania in 1889, Dr. Frazier cast about for a career. His two elder brothers, George and William, having entered the Franklin Sugar Refining Company with their father, his mother insisted that he choose a profession. He agreed to enter the Medical School of the University of Pennsylvania for a year to discover whether or not he found medicine sufficiently interesting to pursue it further.

According to all reports he had a very unhappy time during his first two years in the medical school, fainting twice in the dissecting room. But his father compelled him to stick it out. It was amusing to learn this the other day from Dr. Frazier's sister. My grandfather and Dr. Frazier's father were captains together in the Sixth Pennsylvania Cavalry during the Civil War and great friends afterwards. My memory of the two old gentlemen fighting the War again is quite clear. When irritated, old Mr. Frazier looked and talked like a captain. I am sure if he told his son to stay in the medical school, he stayed. Dr. Frazier inherited many of his father's characteristics.

After graduation from the medical school in 1892 well up in his class, he served internships in the Episcopal and University Hospitals under Dr. John Ashhurst and Dr. J. William White. Ashhurst in those days was the last of the surgeons to wear a frock coat in the operating room. White was his assistant and enthusiastic over the newer methods advocated by Lister

and the German school. At White's suggestion Dr. Frazier spent the next two years, 1895–1896, in Germany studying surgery and surgical pathology under von Bergmann and Virchow. In consequence he had a great admiration for Germany and the Germans. In recognition of this careful training, on his return to Philadelphia he was appointed to the surgical staff of the University and to the teaching staff of the Medical School.

Dr. Frazier's uncle, Mr. C. C. Harrison, was at this time Provost of the University. The Medical School was in a turmoil over entrance requirements, two years of college were all that were needed, and various elderly members of the faculty were slated for prompt replacement. Mr. Harrison wanted a young vigorous broom to clean house. His uncle guaranteed Dr. Frazier a surgical service at the Episcopal Hospital if he would become Dean of the Medical School and clean up the situation. Since he was engaged to marry Miss Mary Gardner of Albany and a surgical service meant financial independence, he accepted. He was Dean for ten hard years until 1910. During that period the entrance requirements were raised to four years in college. The first laboratory of purely surgical pathology in this country was established at the University Hospital and the University of Pennsylvania Medical Magazine was started with Dr. Frazier as editor. Richards, Ricketts, and Edsall were appointed to the faculty, the first time that three men from outside Philadelphia were selected. Dr. Frazier knew that his acceptance of the deanship would involve him in difficulties. The dead-wood on the clinical faculty comprised three of the most respected and beloved of the profession in Philadelphia. So he forced his uncle, Mr. Harrison, to put through the surgical appointment to the Episcopal Hospital before he accepted the Medical School position. He said his appointment precipitated a bitter fight in the Staff and the Board of Managers of that hospital. After the Staff accepted him the vote on the Board was tied twice. Dr. Frazier won only because one of the elderly Board members went to sleep and forgot to vote against him. In retrospect Dr. Frazier often said that if he had known what troubles the deanship would involve him in, he would gladly have kept the old gentleman awake.

Through his association with the Philadelphia neurologists, Dr. S. Weir Mitchell, Dr. C. A. Mills, and especially his classmate in the Medical School, Dr. William G. Spiller, Dr. Frazier soon became interested in neurological surgery. In 1900–1901 with Dr. Spiller, he showed by experimental work on animals that preganglionic section of the sensory root of the fifth nerve was never followed by regeneration of the nerve. In 1901 he cut the sensory root of the trigeminal nerve for the relief of pain in tic douloureux, the first time that this procedure had been carried through successfully. Sir Victor Horsley may have cut the root prior to this date, but his patient did not survive. From this research and clinical observation came forth the modern operative treatment of major trigeminal neuralgia. In 1905, in conjunction with Mills, de Schweinitz, and Weisenburg, he published a monograph on "Tumors of the Cerebellum" in which he could report six cases of suboccipital craniec-

tomy with five recoveries, in three instances following complete or partial removal of the tumor, a much better record than any previously published.

While during the next fifteen years he busied himself with general surgery, neurosurgery and thyroid surgery were his particular interest. In recognition of his leadership in neurosurgery, he was in 1918 appointed consultant to the Surgeon-General in charge of the Neurosurgical Service at Base Hospital No. 11 at Cape May and No. 41 at Fox Hills, Staten Island. He represented the Surgeon-General at the Interallied Surgical Conference in Paris in 1920, with a paper on the results of the treatment of injuries to the peripheral nerves.

In 1922 he was appointed John Rhea Barton Professor of Surgery in the University of Pennsylvania School of Medicine. His ability as an organizer was at once apparent. Within three years he had infused new life into the Department, established fellowships for the teaching of young men, and correlated properly the clinical and research activities.

But, surgery by no means held his entire attention. In 1910 he established with others the Social Service Department in the University Hospital, the second perhaps in this country. In 1914 he organized the Public Charities Association of Pennsylvania and gradually developed it into a state-wide group to the great betterment of the care by the State of its handicapped, feeble-minded, insane, and penal classes. And for this important public work, he was always willing to sacrifice his time and no effort was too great to further its interests.

In 1919 after the War, when he had been appointed John Rhea Barton Professor of Surgery at the University of Pennsylvania, he threw himself into the reorganization of the Surgical Department. We never had had a resident in the University Hospital up to that time. All the work was done by the assistants to the chiefs. There had been three surgical services prior to his appointment, the Deaver Service, the Martin Service, and the Frazier Service. Surgical-wise, you were on either one or the other of these three teams. And if in any way you let your competitors get ahead of you in admitting good surgical cases, you heard of it definitely. One of Dr. Martin's assistants, Dr. Eliason, was a particularly strong Martin man and had thrown his weight about to a very considerable degree in the previous years in defeating Dr. Frazier's effort to build up a large surgical service.

However, when it came to the appointment of the two Clinical Professors of Surgery, Dr. Frazier selected Dr. George P. Muller, who had long been his assistant, and, much to everybody's surprise, Dr. Eliason. When asked why he made this choice, he replied that Eliason was the best teacher we had on the Staff and that the teaching of the students was a very important part of the duty of the Medical School. This, I think, is an excellent illustration of one of Dr. Frazier's major qualifications for leadership. Personalities meant but little to him, if the particular individual selected had other qualities that made his appointment desirable.

The J. William White Laboratory of Surgical Research which had slum-

bered peacefully during the War, and for some time previously, was rejuvenated and Dr. I. S. Ravdin was put in charge.

Dr. Frazier further established a precedent at the University Hospital of geographical full-time service from the head of the Surgical Department. The previous Professors of Surgery always had other hospitals where they ran a service and consequently were not available at all times in the University Hospital for teaching or other purposes. Dr. Frazier moved his office from the doctor's belt on Spruce Street, east of the river, out to West Philadelphia, which in those days was a very daring move for a doctor to make.

His idea was always to give the students on the surgical trimester the best possible teaching and to gather around him a group of young residents for a three-year course in surgery of the finest type. No details seemed to be too small for his attention. I can remember when I was given one of my first teaching assignments. I was handling the class in what I considered to be a very spirited manner when somebody slipped into the top of the amphitheatre. I thought it was a late student and looked up with a little annoyance to see that it was the Professor. He stayed about ten minutes, listened to me teach, and made several valuable suggestions to me later that evening.

He would let nothing interfere with the research program or the residents. Dr. George Muller was one of his oldest friends and had been his assistant at that time for probably ten or twelve years. However, Dr. Muller's idea of the instruction of residents and Dr. Frazier's idea did not agree. Muller felt that a resident was his personal assistant and if the boy happened to be in the Research Department and Muller had a private patient who needed immediate attention, he never hesitated to call the resident away from his research. The very year that Muller had been elected as President of the American College of Surgeons, he and Dr. Frazier broke on this particular point, and Dr. Muller resigned. This, I think, is another good example of Dr. Frazier's insistence upon the importance of good teaching for young men over all other features of a Surgical Department.

During these surgical years with Dr. Frazier, the sub-total avulsion of the sensory root was developed for preservation of corneal anesthesia and the avoidance of keratitis in the eye on the operated side. In 1924 he suggested bleeding a patient who had a cerebellar tumor and a high blood pressure prior to operation and giving him the blood back again at the end of the operation. The final steps were taken in working out the technique in cordotomy. At this time he worked on the suture of the recurrent laryngeal nerve —which is without question the most tiresome, time-consuming operative procedure of which I have any knowledge.

We used suction in the operating room for tics only as early as 1926. Dr. Frazier was never a brilliant operator. He was a good, steady, clean-cut, intelligent surgeon who always tried to do the patient no harm if he could do him no particular good. He was fretful at the operating table which seems to be a common complaint among neurosurgeons. He was particularly fretful about his own personal cleanliness. His shoes were always immaculately

white when he came into the operating room and if by any chance an assistant dropped a bloody patty on those shoes, the orderly would have to come at once and clean them off.

I think the most perfect revenge ever achieved by one of his assistants, as far as Dr. Frazier was concerned, occurred about this time. We were doing a complicated peripheral nerve operation in the upper arm, one of those dreadful cases, after the First World War, which resulted from an osteomyelitis of the humerus caused by a gun-shot wound. These lesions usually suppurated from six to nine months, and three months were always allowed following the healing of the wound before an attempt was made to determine advisability of nerve suture. Fortunately, you younger men don't remember those cases with the tissues a mass of adhesions and all the ordinary anatomical landmarks obliterated. In any event Dr. Frazier preferred to sew up under a continuous stream of saline. We always wore rubber aprons to protect our knees. During the sewing up I noticed that this particular resident was directing his saline mostly on the wound, but every once and a while he would slip some over into Dr. Frazier's lap. This went on for about an hour when I suddenly noticed a puzzled expression on the Professor's face. He looked down angrily at his resident who maintained an expression of bland indifference. The Professor then leaped to his feet and about a gallon of water which this lad had managed to permit to gather in the Professor's lap, where the rubber apron over his knees made a lovely basin, splashed down over his shoes. He never said a word. He simply looked at the resident, raised one eyebrow, handed the irrigating machine over to me and the resident slunk from the operating room. Fortunately, it was about the end of his term of service. I remember again that about three years later this man wrote to Dr. Frazier for a recommendation for an appointment elsewhere. He asked me if I remembered him and I told him I did and recalled all the pleasant things I could think about him. Dr. Frazier looked at me sharply and said, "Isn't he the man who filled my apron with water and ruined my shoes?" I said, "Yes sir, he is." "Well," Dr. Frazier said, "He is a very ingenious fellow. Write him a good letter and I'll sign it."

Rounds with Dr. Spiller were sometimes very amusing. It always irritated Dr. Frazier a good deal in the early days to have Dr. Spiller mark out on the scalp in blue ink the area of the brain he wanted Frazier to expose. Dr. Spiller used a particularly adhesive type of blue dye on these scalps and every now and then would change his mind. The patient would come over sometimes with two or three possible flaps outlined. Then Dr. Frazier would have to send for Dr. Spiller and they would decide solemnly which area Dr. Spiller wanted exposed. He was always very polite to Dr. Spiller.

Dr. Martin, on the other hand, who used to make rounds occasionally, always referred to Dr. Spiller as "Coco," which is supposed to be short for adiadokokinesis. This always irritated Dr. Spiller and you could see him flush and wince when Martin would say jovially, "Well, Coco, what do you think about this particular patient?"

But, Dr. Frazier wasn't without his humorous side. I remember very well

being at French Lick with one of the major societies where Dr. Frazier and I had gone to talk about cordotomy. They had had a very prominent German professor on their program the year before, who had been allotted a half hour and who had spoken an hour and ten minutes. He was on the program again this year and the question was how they could hold him to his time limit and at the same time be polite to him. A good many fairly fantastic suggestions were made and then finally Dr. Frazier, who had been sitting quietly over in a corner, said; "Look boys, I know these foreigners and if you'll do what I tell you, you will find that he will not exceed his time limit. You know when a foreigner goes to a Spa he always likes to be asked to take the waters. You get three or four strong men and meet this gentleman at the station, take him into the hotel, and each of you drink a glass of Pluto water with him. Then get a lot of cocktails and a good dinner in him and see how long he talks." It worked like a charm. The eminent German was allowed thirty minutes, he spoke for twenty-five, a look of pained surprise came over his face, and he stopped. Dr. Frazier said to me afterwards, "I'm sorry we had to fix that gentleman's feet as we did, but if he had spoken too long, you and I never would have caught this train." He stated it quite matter-of-factly, but there was a very definite twinkle in his blue eyes as he said it.

Dr. Frazier was, of course, a member of a number of societies. However, I think the honors that pleased him the most were his election to the Presidency of the Society of Clinical Surgeons, which he had helped to found, his membership and presidency of this group, and above all his election as President of the American Neurological Association. He was also an Honorary Member of the British Neurosurgical Society. He was a Trustee of the University of Pennsylvania and received the degree of D.Sc. from that institution.

One of the most appealing sides of Dr. Frazier's character was his relationship with his children. Unfortunately, Mrs. Frazier died in 1920 and he was left with the four children, ranging from twelve to four. Saturday afternoon and Sunday and two nights a week were always the children's time, as far as he was concerned, and he never let anything interfere with his relationships with his children in spite of all the pressure of business and work. I remember he showed great interest in a youngster named Meade, who was an intern at the Presbyterian Hospital in New York, and asked me, since he presumed that I knew a number of young men in New York, if I could find out anything about him. It just so happened that I could get the information rather readily and turned it over to him. I thought, of course, that he was considering Meade for a residency. I told Dr. Frazier that he was an awfully nice boy, but that apparently he was going to China. "I know," said Dr. Frazier, "that's it. He's going to China and he's engaged to my daughter, Maisie, and he's going to take her to China with him." Two years later Dr. Frazier went to China himself, as a guest of the Rockefeller Foundation, and spoke in their Medical School in Pekin, then going south to visit the newlyweds.

Dr. Frazier was an indefatigable worker, a close economizer of his time

and effort. He had an uncanny ability to strip a problem of its nonessentials and a keen eye for the basic facts. Always driving himself, he expected as much from those around him, although after he applied the spur, he always had just the right words of appreciation. But he did not suffer fools gladly nor did he have time to waste in argument once he had reached his own conclusions. Hence, those who did not know him well found him short and decisive.

But, those of us who were privileged to know Dr. Frazier well and to work with him for a long time, entertained a tremendous respect for his judgment and a high regard for him as an older companion. Four particular attributes stand out, his fine sense of values, his justice, his geniality and wholeheartedness when off duty and at ease, and his devotion to his family. To have as full and busy a career as he did and at the same time never sacrifice his family on the altar of his ambition is the best possible testimony to his sense of proportion.

Dr. Frazier died at his summer home in North Haven, Maine, July 26, 1936. For two years he knew the nature of his illness and what he had to face. For the last eight months he was in constant pain. Up to the end, he took an active interest in all his affairs, uncomplaining, cheerful, keen. He died as he lived, looking forward, always courageous.

# NEUROSURGICAL ASPECTS OF CRYPTOCOCCOSIS*

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CRYPTOCOCCOSIS, sometimes called torulosis, or European blastomycosis, is a fungous disease caused by Cryptococcus neoformans.† The disease is rare, but has shown a surprising increase in incidence in the past decade, undoubtedly concomitant with increasing clinical awareness on the part of the physician.‡

## CAUSATIVE ORGANISM

The causative organism is a small, yeast-like spherule, approximately the size of a red blood cell, which reproduces by budding, and which has neither mycelia nor ascospores. It is surrounded by a mucinous capsule, frequently twice the diameter of the cell, seen as a wide, clear area around the organism, and best demonstrated in India-ink preparations. The fungus grows readily at room or body temperature, ferments no sugars, nor liquefies gelatin. The cryptococci are widespread in nature, occurring with great frequency on the skin and in the intestinal tract of normal individuals. There are several strains, both pathogenic and non-pathogenic, which can be identified by cultural characteristics, agglutination reactions, and animal toxicity experiments. Recently it has been demonstrated that the capsules of cryptococci contain serologically reactive substances, so that specific antisera reacting with the organisms produce a capsular swelling, akin to the Quellung reaction seen between pneumococci and specific antisera.[25] These antigenic properties, however, have been of little use in diagnosis and treatment in human cases. The cryptococci can be distinguished mycologically from Blastomyces dermatitidis, the causative organism of American blastomycosis, since the latter, although the same size and possessing a budding stage as well, has no capsule and produces mycelia.

## GEOGRAPHICAL DISTRIBUTION

Although cryptococcosis has been called European blastomycosis, having first been described in Germany, the great majority of cases have occurred in the United States, with only 30 cases recorded from the European continent.

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† There has been much discussion concerning the mycological nomenclature of this organism, the subject being authoritatively reviewed by Benham.[2]

‡ In a recent review of the literature, 220 published cases of cryptococcosis have been found. In addition, there are more than 30 other known but unreported cases (personal communications), primarily with central nervous system involvement.[6]

## INCIDENCE AND MORTALITY

Cryptococcus neoformans is unique among the fungi in its predilection for invasion of the central nervous system. This readily becomes apparent when it is noted that of a total of 220 reported cases recently reviewed,[6] 178 (81 per cent) exhibited central nervous system involvement. There was a two-to-one preponderance of the male sex in this group.

Study of these 178 cases with central nervous system involvement revealed only 1 case, that of a cryptococcic meningitis, in which the patient could be considered cured, with sulfadiazine the therapeutic agent employed.[23] The majority of these patients (86 per cent) were dead within 1 year, and 70 per cent of these within 3 months of onset. The central nervous system disease is, therefore, a virulent one, although there are several patients reported alive after $2\frac{1}{2}$, 7 and 9 years; these still have evidence of disease activity, indicating a more indolent, but rarer, type of infection.

## DIAGNOSIS

The diagnosis during life in cases of central nervous system involvement was made primarily by observation or isolation of the organism from the cerebrospinal fluid. Thereafter, in order of decreasing frequency, diagnosis was made by biopsy (both local and during exploratory craniotomies) and by culture of blood, urine, and sputum, and of material from nasopharynx, rectum, vagina and pleural cavity. Biopsy or culture established the diagnosis during life in 69 per cent of the central nervous system cases.

## PATHOLOGY

The organisms most likely reach the central nervous system by way of the blood stream, producing three varied types of pathological reaction.

(1) *Meningitis.* Grossly the exudate is found most often at the base of the brain and diffusely in the spinal subarachnoid space. It may vary from rather delicate opacities to dense masses of yellowish-white material primarily in the basilar cisterns and often in the lumbar sac. Where the organisms are concentrated, gelatinous, sometimes amber-colored exudate is encountered.

Histologically, the findings in the leptomeninges are those of a granulomatous meningitis, resembling those seen in tuberculous meningitis, as well as in other fungous infections. It is characterized by chronic inflammation, necrosis of exudate, angiitis, and granulation tissue. In other areas there may be a striking paucity of inflammatory changes, although many organisms may be present, either lying free in the tissues, or phagocytized by Langhans giant cells. This is far more frequent, however, in the meningoencephalitic form of the infection.

(2) *Meningoencephalitis.* In addition to the changes in the leptomeninges described above, a honey-combed appearance of the cerebral cortex, basal ganglia, and thalamus may be encountered, as well as of the roof nuclei of the cerebellum and much of the brain stem. These changes are almost wholly confined to the gray matter.

Histologically, there is meagre evidence of inflammation noted in the leptomeninges and parenchyma. Cryptococci are found abundantly in the subarachnoid space and in the Virchow-Robin spaces of the affected areas of the parenchyma. It is probable that the perivascular spaces have been invaded by direct extension from the subarachnoid space. The Virchow-Robin spaces are hugely distended because of the swollen, gelatinous capsules of the organisms, giving the gross soapsuds appearance described by Stoddard and Cutler,[35] Freeman[14] and others. Injury to the parenchyma is undoubtedly due to the consequent pressure upon adjoining tissue.

(3) *Granuloma.* Granulomata (or torulomas) have been encountered in the cerebrum and cerebellum, some of them being extremely well demarcated, resembling gummas. They may be composed of abundant granulation tissue of vascular origin, or they may consist almost purely of huge masses of swollen organisms. These lesions are more fully discussed below.

## NEUROSURGICAL PROBLEM. CASE REPORTS

Clinically, cryptococcosis of the central nervous system may manifest itself in a variety of ways, simulating encephalitis, tuberculous meningitis, general paresis, brain abscess, brain tumor or spinal cord tumor. An analysis of 178 cases of the disease with central nervous system involvement reveals 42 cases (23 per cent) in which an expanding intracranial or intraspinal lesion was suspected and an operation performed, but in which Cryptococcus neoformans was ultimately proved to be the etiological agent.

The following 2 previously unpublished cases from the Neurological Institute illustrate this problem.

*Case 1.* E.DeM. (NINY #18309-H), a 12-year-old white female, was admitted on Dec. 15, 1933, with the chief complaints of headache, nausea, and vomiting of 6 weeks' duration. The headache was described as frontal in location, occasionally radiated to the occiput, and was associated with intense, non-projectile vomiting. Three weeks after the onset of headache, drooping of the left eyelid was noted, but there was no subjective or objective disturbance of vision, with diplopia specifically denied. Her past history and system review were both negative, except for a right otitis media associated with pneumonia, type organism unknown, 2 years before admission.

*Examination.* She was a well-nourished, but acutely ill young female, who was bedridden. Her temperature was 101.6°, pulse 100, and B.P. 110/80. The deep reflexes were hypoactive throughout, with diminished abdominals and bilateral Babinski and confirmatories. There was moderate stiffness of the neck with bilateral Kernig's sign. The fundi showed 3 to 4 D. of papilledema bilaterally with hemorrhages and exudate. There was ptosis of the left eyelid and bilateral 6th nerve paralysis.

*Laboratory Studies.* Hb. 85 per cent; RBC 5,240,000; WBC 12,250; P 60; L 38; E 2. Sedimentation rate 28 mm./1 hr. X-rays of the skull showed increased convolutional markings and slight atrophy of the dorsum sellae. The CSF revealed 88 cells (90 per cent lymphocytes, 10 per cent polymorphonuclear leukocytes), 544 RBC, protein 100 mg. per cent, and a 2+ Pandy; culture and sugar were not done at this time.

*Clinical Diagnosis.* In view of the diffuse signs, fever, and pleocytosis in the CSF, it was believed that the most probable diagnosis was tuberculous meningitis, with encephalitis and brain tumor to be ruled out. Because of the advancing papilledema and deterioration of vision, ventriculography was done on Dec. 28, 1933, 2 weeks after admission. The lateral ventricles contained a small amount of air and appeared somewhat enlarged. The 3rd ventricle could be seen, but there was insufficient air to permit accurate mensuration or localization.

*Operation.* In view of the absence of localizing findings or of marked hydrocephalus, and because of papilledema, a subtemporal decompression was done to save vision.

*Postoperative Course.* The patient did poorly, with continued signs of meningeal irritation, hypoactive reflexes, and bilateral positive Babinski and confirmatories. She continued to vomit, her pulse was rapid and weak, and the decompression site was extremely tense. Repeated lumbar punctures were required to relieve both headache and the increased CSF pressure. The CSF cell counts varied between 17 and 199 cells/c.mm.; sugar was 40 mg. per cent.

On Jan. 11, 1934, 1 month after admission, it was reported that "torula-like bodies" had been discovered in the CSF removed on Nov. 18, 1933, 1 month prior to admission; further details concerning this lumbar puncture and the clinical course at that time could not be ascertained. Examination of the CSF on Jan. 12, 1934 revealed many round, budding forms on smear, and the culture was reported on the following day as positive for Cryptococcus neoformans.

During the next 10 days she became increasingly drowsy, lethargic, incontinent of urine and feces, and finally comatose. She was treated with potassium iodide by mouth and sodium iodide intravenously. Forced spinal drainage was instituted with simultaneous lumbar and cisternal taps. Sodium iodide (5 per cent) and acriflavine (1:1000) were both given intrathecally by the lumbar route and on several occasions instilled in the cisterna magna. These therapeutic attempts were futile, and there developed a left hemiparesis, immobile pupils, Cheyne-Stokes respiration, and finally a complete spinal block, this being tested with combined cisternal and lumbar puncture. She expired on Jan. 21, 1934, 11 weeks after the onset of her illness. No autopsy was obtained.

*Case 2.* A.M. (P.H. #866465), a 56-year-old Puerto Rican female, was admitted on April 18, 1947 with the chief complaints of pain in her legs of 22 months' duration, with progressive weakness and numbness of both legs, and urinary incontinence of 4 months' duration.

Two years before admission, the patient first noted a severe lancinating pain on the lateral surface of her left calf, extending in 2–3 days into her left foot. The pain was almost unbearable, lasted for 1 week, disappeared for several weeks, only to reappear with full intensity and, in addition, involved the left thigh and hip. The pain again became less severe, but recurred at intervals of a month, lasting several days at a time.

One year after the onset of pain, she consulted an orthopedic surgeon. X-rays of her lumbar spine and pelvis were said to show extensive demineralization and, accordingly, she was placed in a plaster spica, which enclosed her lower abdomen, pelvis, and left leg. The pain was completely relieved by application of the cast, but recurred 1 month later when the cast was removed, and remained constant until 2 months before admission, when it gradually disappeared.

Four months before admission she noted progressive weakness of her left leg and marked numbness of the toes of her left foot. The numbness spread to involve the left calf and thigh and 2 months later, concomitant with the onset of weakness of the right leg, spread to the right lower extremity. On admission, she stated that the numbness extended to the level of her hips.

With the development of numbness and weakness of the legs, the patient noted that she had loss of sensation during defecation. Despite this, she denied fecal incontinence, being warned of the necessity of defecating by an ill-defined sensation of pressure in her perineum. Urinary incontinence developed soon thereafter manifested by frequent dribbling both day and night. A marked swelling of both legs also began 4 months before admission.

*Examination.* She was a well-developed, somewhat obese female, having no pain but unable to walk. The skin over both buttocks was reddened and there was telangiectasia on both legs, with brawny edema of both ankles. B.P. was 146/84; pulse 80.

Pertinent neurological findings: There was marked hypotonia of the muscles of the lower extremities with evident atrophy but no fasciculations were noted. Muscle strength in the upper extremities was normal, while it was markedly decreased in the lower: iliopsoas and gluteal muscles were 25 per cent of normal; other movements of hip were 50 per cent of normal; hamstrings and quadriceps femoris were 25 per cent of normal; there was no visible movement at the ankle. Reflexes were normal in the upper extremities and absent in the lower; abdominal reflexes were present and no pathological reflexes were elicited. There was bilateral loss of position and vibratory sense from L1 down, with diminished touch, pain and temperature in L1 and L2 dermatomes, and absence of these modalities from L3 down.

*Laboratory Studies.* Hb. 12.8 gm.; RBC 4,450,000; WBC 8,250; P 68; L 26; E 4; M 2. ESR 39 mm./1 hr.; NPN 32 mg. per cent; sugar 86 mg. per cent; Kline negative; urine negative. Urine culture: B. coli. Lumbar puncture was performed between L3–4; initial pressure 60 mm. HOH and manometrics showed no rise on jugular compression, but good rise on abdominal strain. Twelve cc. of yellow fluid which clotted immediately were withdrawn: total protein 4,200 mg. per cent; WBC not done because fluid clotted; colloidal gold and Wassermann were negative. X-rays of lumbosacral spine showed only minimal osteoarthritic changes.

*Clinical Diagnosis.* It was believed that the patient had a tumor of the cauda equina, and, in view of the presence of pain as an early symptom, most likely a neurofibroma.

*Operation.* On April 24, 1947, a complete laminectomy of L1–L4 was done by one of us (L.A.M.). A hard mass could then be palpated through the dura. The dura was opened longitudinally and a solid, firm, tenacious, grayish-white mass, occupying almost the entire spinal canal, could be seen extending from the upper portion of the lamina of L1 to the upper portion of the lamina of L4 (Fig. 1). This mass was almost completely surrounded by nerve roots and resembled a neurofibroma externally. The arachnoid, however, was thickened and there was some adherence of the mass to the arachnoid and overlying dura. The nerve roots were separated from the surface of the tumor and an opening was made into the mass with the intention of evacuating the inside piecemeal. Two to 3 cc. of purulent material were encountered upon making this incision and fresh tissue examination revealed Cryptococcus neoformans. It was believed that further attempt at removal would serve only to disseminate the infection throughout the subarachnoid space and the procedure was

terminated. The dura was left open and the wound irrigated with streptomycin solution. It should be noted that adhesions had been freed at the lower end of the granuloma and that the arachnoid was preserved at its upper end, with almost a complete block at T12–L1.

*Pathological Study.* The specimen consisted of a mass of necrotic exudate composed of fibrin, polymorphonuclear leukocytes, and lymphocytes. In irregular spaces within the exudate were many pale, discrete, oval and rounded transparent shining organisms. These were roughly the size of red blood cells and no capsules were seen.

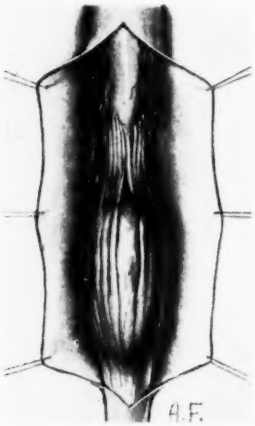


FIG. 1. *Case 2.* Drawing of operative findings, showing cauda equina tumor.

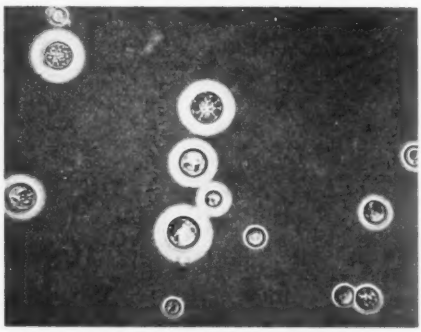

FIG. 2. *Case 2.* Photomicrograph (×450) of culture from granuloma described in text and shown in Fig. 1. India-ink stain to show capsules.

*Cultures* (Fig. 2) from the purulent material obtained at operation were positive for Cryptococcus neoformans. Lumbar puncture, 2 months postoperatively, revealed organisms on culture on one occasion; the remainder of CSF cultures were negative.

*Course.* Postoperatively the patient did moderately well. The incision healed by primary intention. Her CSF was positive for Cryptococcus neoformans on one occasion only and repeated punctures showed a gradual decrease in both cell count and total protein, as well as open manometrics; this latter compared with previous complete spinal block; sugars varied between 18 and 57 mg. per cent. She was treated with injections of Cryptococcus neoformans antigen as well as with intrathecal injections of protoanemonin.* Further attempts at this type of therapy were discontinued, however, because of negative cultures.

During the next few months the patient occasionally ran a low-grade fever. She also complained of severe burning and sticking pains in her lower extremities. Five months postoperatively there was definite return of strength in her quadriceps, iliopsoas, and gluteal muscles, but no return of function in the muscles of her lower

* This therapy was directed by Dr. Beatrice C. Seegal, Department of Bacteriology, College of Physicians and Surgeons, Columbia University. Results will be published elsewhere.

legs. With intensive physiotherapy and foot-drop braces, she was gradually mobilized and could walk poorly with the aid of crutches. Chronaxie studies of the muscles below the knees indicated almost complete degeneration of muscle fibers. Her bladder control improved and she was taken off tidal drainage 4 months postoperatively. She was discharged to Clinic on Dec. 31, 1947, 8½ months after admission. At that time she could maneuver only in a limited fashion on crutches, could void well, still had severe pain in both legs, and had no return of function in the muscles below the knees. She was last seen 3 weeks after discharge, with additional neurological findings of bilateral Hoffmann sign and deafness in her left ear.

A report 2 years later (November 1949) indicated that she was unable to move her lower extremities and had been confined to a wheelchair for the past year. Otherwise she was in good health and had gained weight. There was no evidence of further central nervous system involvement.

*Comment.* This case is of interest in that it simulated a spinal cord neoplasm, e.g., a neurofibroma of the cauda equina. Whether the organisms could have been seen or cultured from the CSF from the first lumbar puncture is doubtful, in view of the tumor-like appearance of the lesion at operation. However, it is worth noting that fluid of this sort, i.e., which clots, should be citrated and subjected to the routine laboratory examinations. The apparently permanent loss of muscle power in the legs was probably caused by the extensive root damage, as seen at operation. The return of CSF protein and manometrics to normal may be explained by the fact that the dura was left open, since there was still a large mass within the spinal canal when the operation was terminated. Therapeutic measures are difficult to evaluate. The organism was found to require more than 30 μgm. of streptomycin per cc. to inhibit growth, so it would seem that this drug was of no use in the concentrations used. Protoanemonin therapy was well tolerated, but the persistently negative cultures before starting the drug invalidate any conclusions of efficacy. Most significant of all is that 31 months following operation there was still no clinical evidence of dissemination of the organism throughout the subarachnoid space; cultures of the CSF have not recently been reported.

## REVIEW OF LITERATURE

A review of the literature reveals 42 cases in which neurosurgical procedures were performed, with a total of 62 operations (Table 1). There were 24 exploratory operations: 12 supratentorial, 9 infratentorial, and 3 laminectomies. In addition, 11 decompressive procedures, 6 pneumoencephalograms and 21 ventriculograms were done.

In the 42 cases (Table 2) 9 tumors, or granulomata, were found at operation and 2 at autopsy (these latter 2 had had negative neurosurgical procedures, i.e., normal ventriculogram in one, and 4 trephinations in the other). It is interesting to note that in 2 cases, those of Swanson and Smith[36] and of Hassin,[19] there were isolated granulomata with no evidence of meningitis found at autopsy.

There were 4 cases in which a leptomeningitis was found at operation,

TABLE 1

*Operative procedures—42 cases*

Supratentorial explorations—12
- Craniotomy—6
  - Left parietal—2[15,42]
  - Right frontal—1[30]
  - Site unknown—3[24,35,38]
- Trephination—6
  - Right parietal—2[31]
  - Site unknown—4[10,19,28]
- Ventriculogram—21[1,4,8,10,12,14,17,22,26,27,29,31,34,10*]
- Infratentorial explorations—9
  - Suboccipital craniectomy—8[10,12,14,17,21,27,36,40]
  - Trephination (cerebellum)—1[11]

Laminectomy—3
- L1-4—1†
- Site unknown—2[16]

Decompression—11
- Subtemporal—10[1,10,15,18,22,24,35,39,40*]
- Tentorial splitting—1[10]

Pneumoencephalogram—6[10,11,21,39]

Total: 62 operations in 42 patients

* Authors' Case 1.
† Authors' Case 2.

3 of these of basilar type. In 9 cases explorations and trephinations were negative. Of significance is the fact that the diagnosis of cryptococcosis was made by biopsy of the leptomeninges and cortex in both supra- and infratentorial explorations and trephinations, by culture of the ventricular fluid during ventriculography in one case, and by culture of the subarachnoid fluid during subtemporal decompression in another.

Involvement of the spinal cord is rare, only 10 cases of cryptococcic

TABLE 2

*Granulomata found in operated cases*

| Author | Year | Operation | Lesion |
|---|---|---|---|
| 1. Gáspár[15] | 1929 | Lt. parietal craniotomy | Large, 6 cm. granuloma. |
| 2. Freeman[14] | 1931 | Suboccipital craniectomy | Tiny, 3 mm. nodule, rt. cerebellar hemisphere. |
| 3. Mook & Moore[24] | 1936 | Rt. ?frontal craniotomy | Pea-sized cortical lesion. |
| 4. Dickmann *et al.*[12] | 1942 | Suboccipital craniectomy | Nodular, 3.5 cm. mass. lt. cerebellar hemisphere. |
| 5. Swanson & Smith[36] | 1944 | Suboccipital craniectomy (2 operations) | *Two lesions: (1) Rt. cerebellar tonsil; (2) Rt. cerebellar hemisphere. |
| 6. Cox & Tolhurst[10] | 1946 | Ventriculogram, normal | At necropsy, cyst-like lesion, rt. hippocampus, compressing temporal horn. |
| 7. Cox & Tolhurst[10] | 1946 | Occipital trephination (left) | At necropsy, two lesions: (1) 2 cm. mass, lt. occipital pole, found at operation; (2) rt. frontal lobe. |
| 8. Hassin[19] | 1947 | Trephinations; 4 burr-holes negative | *At necropsy, 5×3 cm. lesion, lt. cerebellar hemisphere. |
| 9. Carton & Mount Case 2 | 1951 | Laminectomy, L1-4 | Cauda equina granuloma with suppuration in center. |

* No meningeal disease present.

TABLE 3

*Cryptococcosis of the spinal cord*

| Author | Year | Spinal Cord Pathology | Clinical Course |
|---|---|---|---|
| Swift & Bull[37] | 1917 | Acute myelitis, dorsal cord; scrapings showed fungi. Many yeast-like cells on section of cord. | Headache, failing vision. High temperature. Left pupil greater than rt. Deaf. L.P. positive 2 days before death. |
| Semerak[32] Case 2 | 1928 | Endarteritis, intrinsic and subarachnoid vessels. Lymphocytic infiltration, parenchyma. Penetration into and along sheaths of peripheral nerves. Organisms present. | No data. |
| Smith & Crawford[33] | 1930 | Adherent dura; compression lumbodorsal cord. Superficial and central granulomata. No smear or cultures. | Scapular tumor, thought to be Hodgkin's disease, responding to radiotherapy. Cranial nerve signs. Spastic paralysis rt. arm. Paralysis both legs, 10 mos.* |
| Freeman[14] Case 1 | 1931 | No intrinsic pathology. Cord surrounded by exudate; perivascular penetration. | Headache, fever, paralysis limbs, progressing to coma. No specific cord symptoms. |
| Heinrichs[20] | 1932 | Involvement of dura, T11–12. Destruction T11–12 vertebrae. ? Peripheral nerve involvement. | Chest-wall tumor; intercostal nerve pain. Meningeal signs. No spinal cord symptoms. |
| Fitchett & Weidman[13] | 1934 | Several granulomata in cord made up of endothelial cells; no organisms seen. | Hodgkin's disease. Then meningeal symptoms and generalized cryptococcosis. |
| Goodhart & Davison[16] Case 2 | 1937 | Complete demyelinization, T10. Thickened meninges, T10. Perivascular infiltration, posterolateral arteries; a few organisms. | Leg pains and urinary incontinence. Laminectomy; no tumor. Sudden paralysis of legs; 2nd op.; no tumor. Meningitis. Death.* |
| Burton[5] | 1941 | "Motor tracts of cord." | Hodgkin's disease. Headache and meningitis, dying in coma. No data on cord symptoms. |
| Reeves, Butt & Hammack[30] Case 6 | 1941 | One tubercle deep in white matter of cervical cord. | Headache, stiff neck, hypoactive reflexes. No cord symptoms. |
| Carton & Mount Case 2 | 1951 | Cauda equina tumor. Involvement of nerve roots. Purulent material in center of granulomata; smear positive. | Weakness and pain in lower extremities. Urinary incontinence. Complete spinal block. Laminectomy. Diagnosis by smear. Still alive.* |

* Spinal cord symptomatology.

lesions having been found in the literature (Table 3). Only 3 of these patients showed spinal cord symptomatology, the remainder having coincidental lesions demonstrated at necropsy.

## DISCUSSION

From these data and study of the reported case histories, the following points should be stressed:

(1) Localized cryptococcic granulomata can occur without other evidence of central nervous system disease. They may, therefore, be the only central nervous system manifestation of systemic infection with the organism.

(2) Localized cryptococcic granulomata can occur in conjunction with a diffuse or circumscribed leptomeningitis.

(3) Diffuse cryptococcic leptomeningitis, without specific granulomata

TABLE 4

*Radiological findings*

| | | |
|---|---|---|
| **Skull X-rays*** | | |
| Normal | | 18 |
| Increased CSF pressure | | 8 |
| Separation of sutures | 1 | |
| Increased convolutional markings | 2 | |
| Atrophy of dorsum sellae and/or clinoids | 5 | |
| Displacement of pineal and choroid glomus | | 1 |
| Calcification | | 3 |
| Bone destruction | | 1 |
| | Total cases | 31 |
| **Ventriculography** | | |
| Normal | | 4 |
| Hydrocephalus, no tumor | | 6 |
| Posterior fossa tumor | | 2 |
| Porencephalic cyst | | 1 |
| Unsuccessful or insufficient data | | 8 |
| | Total cases | 21 |

* Data available in only 31 of 178 cases of central nervous system involvement.

or collections of organisms, can produce the picture of an expanding intracranial lesion, and may occasionally do so with a negative CSF.

(4) Clinically, the occurrence of papilledema in 20 (47.6 per cent) of the 42 patients operated upon is of significance; papilledema was also present in 40.2 per cent of 178 cases of central nervous system involvement in the larger series.[6] The mechanism of the papilledema is obvious from the previously described pathology, being primarily obstructive, but occasionally space-occupying, in nature. Equilibratory disturbances, found historically in 21 per cent and in 8.4 per cent on physical examination in the larger series when coupled with papilledema, have served to direct attention to the posterior fossa, particularly when lumbar puncture was felt to be contraindicated because of the papilledema. Actually, the initial diagnosis of an expanding intracranial lesion was made more often in the total number of centra

nervous system cases than the occurrence of papilledema would indicate. It was considered in many cases without papilledema, only to be revised when CSF cultures revealed cryptococci; in these cases, of course, operation was not performed, except in a rare instance to save vision.

(5) Radiologically, cryptococcosis may also simulate an expanding intracranial lesion. This is illustrated in Table 4 in which 31 available reports (from the larger series[6]) are tabulated. Increased intracranial pressure was evidenced by increased convolutional markings, suture separation, and atrophy of the dorsum sellae and clinoids. In addition, displacement of pineal gland and of choroid plexus, calcification, and bone destruction were recorded. The ventriculographic findings deserve no particular comment.

(6) The cerebrospinal fluid findings may be extremely variable. There are certain points which may be suggestive of the disease (as well as of tuberculous meningitis): (a) Lymphocytic pleocytosis, although polymorphonuclear leukocytes may be present in large numbers; (b) moderately increased protein; (c) frequently markedly diminished or even absent sugar; (d) diminished chlorides; and (e) elevated pressure. The fluid may occasionally be turbid or xanthochromic in appearance. The finding of the organisms on smear or culture, however, is diagnostic. It should be noted that the organisms may not grow out for a number of days and cultures should be kept for 2 weeks before being declared negative.

## SUGGESTIONS FOR ESTABLISHING DIAGNOSIS

If cryptococcosis, and other fungous invaders of the central nervous system[3] are considered in the differential diagnosis of both meningitis and suspected expanding intracranial lesions, the diagnosis will be made more often during life. This would seem to be increasingly important with the advent of newer antibiotics with fungicidal activity.

It is suggested that the laboratory procedures mentioned in the following paragraphs be performed when there is evidence of (a) an unexplained CSF pleocytosis or (b) a reduced CSF sugar. In addition, (c) systemic lesions, i.e. of lung, bone, skin, etc., in the presence of neurological signs and symptoms of undetermined etiology, make it imperative to rule out fungous disease. Finally, (d) the occasional association of cryptococcosis and the lymphomatous diseases (Hodgkin's, lymphosarcoma, leukemia, etc.[9]), would warrant extensive studies for fungi in all suspected or proved lymphomas, with or without central nervous system involvement. Ideally, these procedures might be done routinely, just as the Wassermann reaction, bacterial cultures and CSF sugar determinations are so done. However, limitations of a practical nature, such as relative infrequency of occurrence, and the lack of adequate mycological facilities, make the above indications desirable.

(1) Specimens of CSF, both from lumbar puncture and intracranial procedures, should be cultured for fungi on Sabouraud's medium.

(2) Collection of CSF should be performed in a sterile tube for microscopic examination of this material on a clean counting chamber. This will

eliminate the danger of ignoring so-called "contaminant fungi," and enable proper evaluation to be given to any yeast or fungus-like organisms seen. Often the cryptococci may be present without capsules and simulate red blood cells, for which they not infrequently have been mistaken in the reported cases. It should be remembered that a fungus may be present if so-called "red blood cells" persist after addition of acetic acid to the counting fluid.

(3) If fungus-like forms are suspected, particularly the cryptococcus, an India-ink slide or hanging-drop preparation should be examined. This will clearly indicate the halo-like capsules characteristic of the organisms.

(4) The pathologist must be alert to the possibility of encountering the disease when confronted with tissue biopsy material during operation. In this type of specimen, there is an occasional resemblance of some of the cystic lesions encountered at operation to the gliomas, and certainly the clinical course might influence the surgeon towards the latter diagnosis.[36] The organism can be seen clearly in frozen sections and in vital-staining preparations.

(5) Fungus cultures should be employed at the autopsy table whenever there is suitable indication for bacterial cultures.

(6) Certain other laboratory procedures may reveal the causative organism. These, of course, are blood, sputum, urine, nasopharyngeal and ear cultures, as well as cultures from gastric washings and from cutaneous lesions. These may be positive in the systemic or generalized form of the disease and yield the proper clue to the intracranial diagnosis.

## TREATMENT

From the evidence already presented, and from a review of various therapeutic agents tried previously in the disease,[7] it is apparent that therapy has been uniformly unsuccessful. The most suggestive approaches to this problem at the present time, although by no means the definitive therapeutic agents, center around actidione, vaccine therapy, and fever therapy;* the problem of therapy of this disease is therefore still unsolved.

## SUMMARY

1. The causative organism, distribution, mortality, and pathology of central nervous system cryptococcosis are briefly discussed.

2. Attention has been directed to the neurosurgical implications of the disease, with particular regard to simulation of expanding lesions and operative procedures performed in the cases reviewed and reported.

3. The laboratory detection of cryptococcosis, and of other fungous diseases, is outlined and indications are given for the employment of these procedures; the final diagnosis of a fungous disease is a cultural one.

4. Brief mention is made of therapeutic trends in this almost uniformly fatal disease.

* Actidione and fever therapy have been tried in 3 cases at the Neurological Institute. Results are reported elsewhere.[7]

## ADDENDUM

Recently a third patient was operated upon by one of us (L.A.M.). The history, neurological examination, and ventriculogram indicated an expanding lesion within the posterior fossa. Exploration showed a soft left cerebellum which bled readily. The ventricular fluid contained "yeast-like" organisms and subsequent cultures were positive for cryptococci. Biopsy of the cerebellum revealed cryptococci. The patient succumbed to a fulminating cryptococcic meningitis despite intramuscular, intraventricular, and intraspinal treatment with actidione.

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## REFERENCES

1. Allende, G. Meningitis à torula. *Prensa méd. argent.*, 1910, *27:* 816–818.
2. Benham, R. W. (In preparation)
3. Benham, R. W., and Georg, L. K. Allescheria boydii, causative agent in a case of meningitis. *J. invest. Derm.*, 1948, *10:* 99–110.
4. Burger, R. E., and Morton, C. B. Torula infection. A review and report of four cases. *Surgery*, 1944, *15:* 312–325.
5. Burton, R. M. Lead encephalopathy complicating torula infection. *W. Va. med. J.*, 1941, *37:* 212–214.
6. Carton, C. A. Cryptococcosis of the central nervous system. (In preparation)
7. Carton, C. A. Treatment of central nervous system cryptococcosis. (In preparation)
8. Cohen, M. Binocular papilledema in a case of torulosis associated with Hodgkin's disease. *Arch. Ophthal., N. Y.*, 1944, *32:* 477–479.
9. Collins, V. C. Association of cryptococcosis and the lymphomas. (In preparation)
10. Cox, L. B., and Tolhurst, J. C. Human torulosis. A clinical, pathological and microbiological study with a report of thirteen cases. *Melbourne & London: Melbourne Univ. Press*, 1946, xi, 149 pp.
11. De Busscher, J., Scherer, H. J., and Thomas, F. La méningite à torula. (Contribution à l'étude des localisations nerveuses des infections à pseudolevures). *Rev. neurol.*, 1938, *70:* 149–168.
12. Dickmann, G. H., Veppo, A. A., and Negri, T. Torulopsis del sistema nervioso central (cerebelo) de forma tumoral. *Rev. neurol. Buenos Aires*, 1942, *7:* 347–360.
13. Fitchett, M. S., and Weidman, F. D. Generalized torulosis associated with Hodgkin's disease. *Arch. Path.*, 1934, *18:* 225–244.
14. Freeman, W. Torula infection of the central nervous system. *J. Psychol. Neurol., Lpz.*, 1931, *43:* 236–345.
15. Gáspár, I. Blastomycotic meningo-encephalitis. Report of a case. *Arch. Neurol. Psychiat., Chicago*, 1929, *22:* 475–486.
16. Goodhart, S. P., and Davison, C. Torula infection of the central nervous system. *Arch. Neurol. Psychiat., Chicago*, 1937, *37:* 435–438.
17. Greenfield, J. G., Martin, J. P., and Moore, M. T. Meningo-encephalitis due to Cryptococcus meningitidis (T. histolytica) with report of a case. *Lancet*, 1938, *2:* 1154–1157.
18. Hall, G. W., Hirsch, E. F., and Mock, H. Torula histolytica meningo-encephalitis. *Arch. Neurol. Psychiat., Chicago*, 1928, *19:* 689–694.
19. Hassin, G. B. Torulosis of the central nervous system. *J. Neuropath. exp. Neurol.*, 1947, *6:* 44–60.
20. Heinrichs, H. Beitrag zur Pathologie der Blastomykosen. *Zbl. allg. Path. path. Anat.*, 1932, *53:* 422–428.
21. Horrax, G. Personal communication.
22. Magruder, R. G. A report of three cases of torula infection of the central nervous system. *J. Lab. clin. Med.*, 1939, *24:* 495–499.

23. Marshall, M., and Teed, R. W. Torula histolytica meningoencephalitis. Recovery following bilateral mastoidectomy and sulfonamide therapy: preliminary report. *J. Amer. med. Ass.*, 1942, *120:* 527–529.
24. Mook, W. H., and Moore, M. Cutaneous torulosis. *Arch. Derm. Syph., N. Y.*, 1936, *33:* 951–965.
25. Neill, J. M., Castillo, C. G., Smith, R. H., and Kapros, C. E. Capsular reactions and soluble antigens of Torula histolytica and of Sporotrichum schenckii. *J. exp. Med.*, 1949, *89:* 93–106.
26. Neuhauser, E. B. D., and Tucker, A. The roentgen changes produced by diffuse torulosis in the newborn. *Amer. J. Roentgenol.*, 1948, *59:* 805–814.
27. Nichols, I. C. Torula meningoencephalitis. Report of a case. *R. I. med. J.*, 1941, *24:* 221–222.
28. Nieuwenhuijse, P. Over infectie met torula. *Ned. Tijdschr. Geneesk.*, 1935, *79:* 611–613.
29. Pusch, L. C. Personal communication.
30. Reeves, D. L., Butt, E. M., and Hammack, R. W. Torula infection of the lungs and central nervous system. Report of six cases with three autopsies. *Arch. intern. Med.*, 1941, *68:* 57–79.
31. Rogers, J. B., and Jelsma, F. Torula meningo-encephalitis. *J. Amer. med. Ass.*, 1933, *100:* 1030–1031.
32. Semerak, C. B. Torular leptomeningitis. *Arch. Path.*, 1928, *6:* 1142–1145.
33. Smith, F. B., and Crawford, J. S. Fatal granulomatosis of the central nervous system due to a yeast (torula). *J. Path. Bact.*, 1930, *33:* 291–296.
34. Stenvers, H. W. Torula-infectie van het centrale zenuwstelsel. *Ned. Tijdschr. Geneesk.*, 1934, *78:* 3361–3366.
35. Stoddard, J. L., and Cutler, E. C. Torula infection in man. A group of cases, characterized by chronic lesions of the central nervous system, with clinical symptoms suggestive of cerebral tumor, produced by an organism belonging to the torula group (Torula histolytica, N. Sp.). *Monogr. Rockefeller Inst. med. Res.*, No. 6, 1916, 98 pp.
36. Swanson, H. S., and Smith, W. A. Torular granuloma simulating cerebral tumor. Report of two cases. *Arch. Neurol. Psychiat., Chicago*, 1944, *51:* 426–431.
37. Swift, H., and Bull, L. B. Notes on a case of systemic blastomycosis—blastomycotic cerebrospinal meningitis. *Med. J. Aust.*, 1917, *2:* 265–267.
38. Tinney, W. S., and Schmidt, H. W. Torula infection. *Med. Clin. N. Amer.*, July 1944, *28:* 950–956.
39. Voyles, G. Q., and Beck, E. M. Systemic infection due to Torula histolytica (Cryptococcus hominis). 1. Report of four cases and review of the literature. *Arch. intern. Med.*, 1946, *77:* 504–525.
40. Wade, L. J., and Stevenson, L. D. Torula infection. *Yale J. Biol. Med.*, 1941, *13:* 467–476.
41. Watts, J. W. Torula infection. A review and report of two cases. *Amer. J. Path.*, 1932, *8:* 167–192.
42. Wilhelmj, C. M. The primary meningeal form of systemic blastomycosis. *Amer. J. med. Sci.*, 1925, n.s. *169:* 712–721.

# FOCAL EPILEPSY OF PSYCHOMOTOR TYPE

## A PRELIMINARY REPORT OF OBSERVATIONS ON EFFECTS OF SURGICAL THERAPY*

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PSYCHOMOTOR seizures (psychic equivalents, ictal automatisms, fugue states) represent the commonest type of focal epilepsy, according to Gibbs.[15] Long ago Hughlings Jackson[19] described complicated psychic seizures, consisting largely of illusions of perception and of hallucinations, under the heading of "dreamy states." Due to the frequent association of purposeful behavior and movement with such clouded mental states, Gibbs, Gibbs and Lennox,[16] in 1937, coined the phrase "psychomotor seizures," and described generalized electroencephalographic abnormalities, consisting of flat-topped waves formed by a sequence of positive spikes. Penfield[27] observed that such rhythm and seizures may occur in lesions of one temporal region. Two refinements of electroencephalographic technique, originating from the laboratory of the Gibbs',[10,11,13] have led to the disclosure of spontaneous electrographic spiking from the anterior temporal areas in over 90 per cent of patients having clinical psychomotor epilepsy.

In view of the observations that these patients are rarely controlled by such medications as are available at present, and that they have localized cerebral involvement in a relatively "silent area," surgical removal of the discharging region was suggested in severe cases (Gibbs *et al.*[14]).

A preliminary report on the therapeutic results of temporal lobotomy for psychomotor epilepsy was presented by Bailey and Gibbs[2] in 1948. Their further observations have been encouraging, indicating that lobotomy is less effective than cortical excisions.[3]

During the past two years, 23 patients, each manifesting psychomotor epilepsy, failing to respond to systematic medical therapy, and demonstrating spontaneous electroencephalographic spiking in the anterior temporal area, have been investigated surgically. Ninteeen of these patients were committed to the Arizona State Hospital. The remaining 4 patients, totally dependent upon their relatives, were operated upon at the Good Samaritan Hospital, Phoenix, Arizona. We wish to emphasize that this is a preliminary report of our observations and that it is not our opinion that any of the patients who have been rehabilitated can be certified as cured. It is recognized that seizures may recur years after apparent termination of the malady.

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It is believed, however, that thoughtful correlation of clinical and laboratory data of this type will supplement our knowledge of an important, but incompletely studied, functioning area of the brain—the temporal lobe.

## DIAGNOSIS

There are few entities in neurology that require more scrutiny than the selection of an epileptic patient for surgical intervention. Penfield[26] has emphasized the necessity of careful study of the physiologic mechanism and the pathologic cause in each individual case.

The method of evaluation of our cases has been as follows:

(1) *History.* In most cases, the description of the attacks was such that a diagnosis of psychomotor epilepsy could be made on this basis alone; occasionally, it was necessary to observe the patient during such an attack to verify this point. Such attacks can occur in the absence of convulsions (grand mal) or minor (petit mal) seizures, or may be associated with them. Instances in which the attacks began with clouded mental states, purposeful movements, and were followed by aphasia, clonic movements of the right side of the face and a generalized convulsion, were observed. The chief clinical features of psychomotor epilepsy have been described (Gibbs *et al.*[14]) in the following manner:

> The patient becomes confused, and as a rule, amnesic, but does not usually lose consciousness. His movements appear purposeful, but are generally poorly coordinated, and his manner is frequently negativistic. In general, his behavior is that of a person acting out a bad dream. Often during the seizure there are manifestations of fear or rage with screaming or shouting. In most seizures the movements are simple, repetitive, and more or less automatic; for example, smacking the lips, wringing the hands, or plucking the clothes. Usually in the inter-seizure period severe personality disorders are present. These may be of such high degree that the patient is classified as psychotic. Irrespective of medication, hypersomnolence is common.

It has been observed that these disorders are frequently classified as epilepsy with psychosis, hysteria, psychopathic personality or schizoid psychosis. A higher incidence of psychomotor epilepsy has been reported (Belinson[4]) among institutionalized epileptics. Gibbs[14] has pointed out that the "epileptic personality" is rare in patients with other types of epilepsy and he attributes much of this disorder to "seizure activity" in the anterior temporal area.

A history of cranio-cerebral *trauma* of severe degree, preceding the initial attack, was obtained in 14 of the 23 patients. No case of neoplasia was observed in our group, although this has recently been reported by Bailey and Gibbs.[3] None of the patients reported were benefited by the usual antiepileptic substances, singly or combined, even in high dosages. Phenobarbital was observed to aggravate the psychomotor attacks, and in some instances Phenurone intensified the psychiatric abnormalities.

(2) *Examinations.* Physical, neurological, psychiatric and Wechsler-Bellevue performance examinations were made for the purposes of cerebral

localization, determination of surgical risk, and comparison with postoperative states.

(3) *Electroencephalography.* Serial electroencephalography is indispensable for the laboratory evaluation of epileptic patients. Model III, 8-channel Grass electroencephalographs were utilized. "Monopolar" recordings, reference electrodes on either or both ears, or in the suboccipital area, with spontaneous or pentothal sodium induced *sleep*, were carried out in each case. It was observed that abnormalities were more common during sleep than in the waking or hyperventilated states. Focal EEG abnormalities (spontaneous spiking, slow spikes) were localized to the anterior temporal areas in each of the 23 cases (Table 1).

TABLE 1

*Anterior temporal localization by EEG*
*23 cases of psychomotor epilepsy*

| | |
|---|---|
| *Left* | —10 cases (8, 12, 13, 14, 18, 19, 20, 21, 22, 23) |
| *Right* | — 4 cases (3, 6, 9, 10) |
| *Bilateral*— | 9 cases |
| *Left worse* | —6 cases (1, 4, 11, 15, 16, 17) |
| *Right worse* | —3 cases (2, 5, 7) |

(4) *Pneumo-encephalography.* Pneumographic visualization of the ventricular and subarachnoid systems was carried out in 21 of the 23 patients to determine the presence or absence of gross structural abnormalities. Findings produced by a traumatic cicatrix have been thoroughly described by Foerster and Penfield,[8] and Penfield.[25]

(5) *Surgical Indications. Indications for Electrocorticography.* Surgical intervention is considered only if the patient is unmanageable with drugs, and if the seizure pattern, and EEG studies localize the epileptogenic focus. The economic, social, and medico-legal aspects of the problem merely serve to intensify the search for some more effective form of therapy. Electrocorticography aids in the demarcation of the epileptogenic focus and was utilized in every case except Case 1.

## OPERATING ROOM TECHNIQUES

(1) *Pre-operative Medication.* Anti-epileptic substances are withheld for 24 hours prior to surgery. Pre-medication consists of morphine sulfate gr. 1/6 and scopalamine gr. 1/200.

(2) *Anesthesia.* It has been our experience that the type and depth of surgical anesthesia determine to a great degree the success of obtaining spontaneous electrocorticographic abnormalities. Pentothal sodium, nitrous oxide, and oxygen, with endotracheal intubation administered by an anesthesiologist has proven to be highly satisfactory for this type of work. This is supplemented by the infiltration of the scalp with 1 per cent procaine.

(3) *Craniotomy.* A generous osteoplastic craniotomy is made, exposing the entire lateral aspect of the temporal lobe, at least 7–8 cm. from the tip

posteriorly and adjacent areas of the frontal and parietal cortex. It has been found to be helpful in facilitating a low temporal exposure of this type to open the temporal fascia well anteriorly, thereby eliminating the temporal muscle from encroaching on the accessible cortex. Pathology, if present, is noted, and an operative sketch is made.

(4) *Electrocorticography.* (A) The *cortical electrode assembly* (Grass-Gibbs) is fixed to the calvarium, and accessible cortex is covered with the wick electrodes. The electrode placements are recorded. Recordings are made at varying depths of anesthesia and over the entire area. (B) *Depth electrode* (Grass-Bailey) studies are then made, through the focus, if found, synchronously with the cortical studies. When accurate localization of the electrographic focus has been obtained, surgical removal is carried out, if feasible.

(5) *Anterior Temporal Lobectomy.* This procedure is carried out by means of subpial dissection of the superior temporal convolution downward and away from the insula to a depth sufficient to expose the incisura cerebelli. A transection of the temporal lobe, utilizing suction and silver clips, is carried out at a point posteriorly, determined by the above studies, in some cases including the hippocampal gyrus and uncus (the anterior portion).

(6) *Electrocorticography* is repeated with particular interest in the adjacent cortex and exposed insular surface. Occasionally it has been found necessary to remove more tissue posteriorly.

(7) *Postoperative Medications.* The same anti-epileptic substances, previously ineffective, are prescribed postoperatively. The postoperative care is similar to that necessary for craniotomies.

## PATHOLOGY

*Gross pathology* (Table 2) was evident at the time of surgery in 6 cases (12, 13, 16, 21, 22, 23). This consisted of atrophy and meningocortical cicatrization of varying degrees in the exposed anterior temporal area (Fig. 1). *Microscopic pathology* was found in the surgical specimens in 14 cases (1, 3, 7, 9, 14, 18, 19, 20 and the above). These changes were essentially ischemic ganglion cell disease, and hyperplasia of the pia-arachnoid. The remaining cases (9 patients) showed no pathologic changes, grossly or microscopically, but 1 of these (Case 15) had no tissue removed.

TABLE 2

*Temporal lobe pathology*
*23 cases of psychomotor epilepsy*

| |
|---|
| *Gross Pathology*—6 patients |
| Meningo-cortical cicatrix |
| Atrophy |
| (12, 13, 16, 21, 22, 23) |
| *Microscopic Pathology*—14 patients |
| Ischemic ganglion cells |
| Hyperplasia of pia-arachnoid |
| (1, 3, 7, 9, 14, 18, 19, 20 and above) |

FIG. 1. (Top) Cortical atrophy, meningocortical cicatrix, involving middle and inferior temporal convolutions near temporal pole. Anastomotic vein of Labbé is seen separating this area and the superior temporal convolution, anteriorly, draining from the Sylvian area. (*Case 21:* 36-year-old Papago Indian with history of severe head injury when 8 years of age, complicated by psychomotor seizures at 9, and convulsions at 14.)

FIG. 5. (Bottom) Anterior temporal lobectomy, 4.5 cm. from temporal tip, left side, in *Case 22*. Top is anterior. Note transection of temporal horn by the lobectomy and exposure of the insula. (Figs. 2 and 3 respectively illustrate electrocorticography before and after this resection.)

## ELECTROCORTICOGRAPHY

Close correlation was found between the pre-operative clinical and electroencephalographic localization and the findings obtained by electrocorticography (Figs. 2 and 3). Spontaneous spiking was not obtained in Cases 10 and 15. In 4 cases (9, 14, 17, 21) the focus would have been missed without

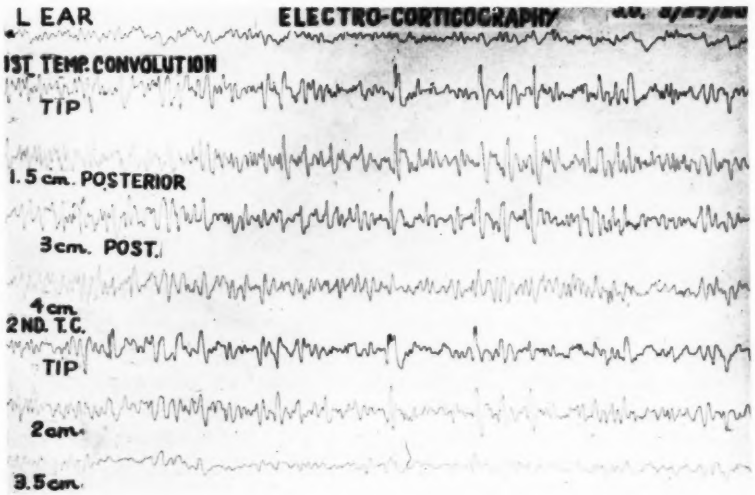


FIG. 2. Electrocorticography, with localization of spike focus to anterior 4 cm. of superior and middle temporal convolutions, during pentothal sodium anesthesia. (*Case 22:* 22-year-old male, with history of gunshot wound of left temporal area when 11, complicated by psychomotor seizures at 13 years of age.)

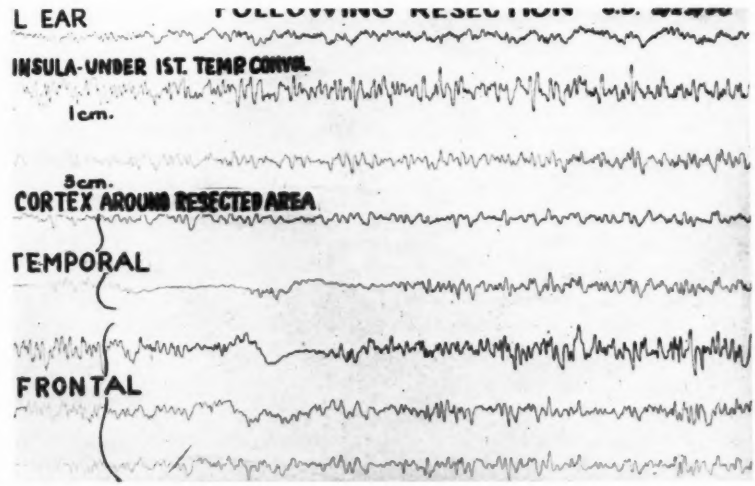


FIG. 3. Electrocorticography, following anterior temporal lobectomy in *Case 22*, with particular reference to adjacent cortex, including the insula.

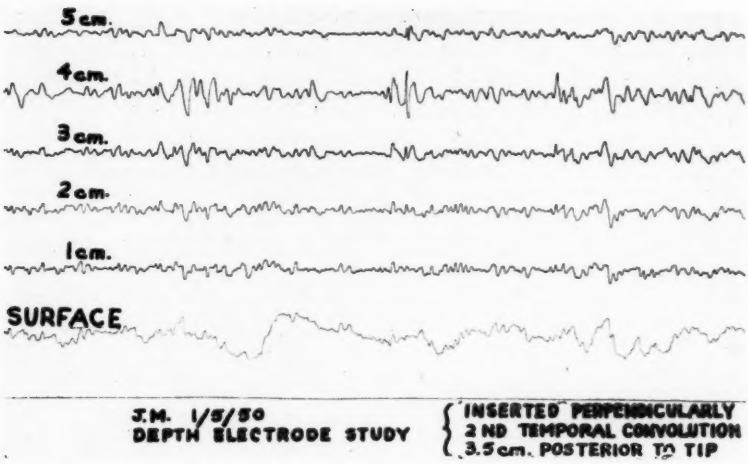


FIG. 4. Depth electrode study, localizing spike focus, on medial surface of temporal lobe, adjacent to insula, 3.5 cm. posterior to temporal tip. Position identified in X-ray by Cushing clip and anterior temporal lobectomy. (*Case 14:* 33-year-old ex-premedical student, with history of severe head injury at 15, transient homonymous hemianopsia, complicated by psychomotor epilepsy 10 years later.)

depth electrode studies (Fig. 4). In all but 3 cases (Table 3*) the focus was found to be in the anterior 4 cm. of the temporal lobe, laterally, inferiorly

TABLE 3

*Electrocorticography*
*23 cases of psychomotor epilepsy*

| | | |
|---|---|---|
| *Spontaneous spike discharges* | | 21 cases |
| *Anterior 4 cm. Temporal Lobe* | | |
| Superior Temp. Convolution (3′, 6′, 7, 8, 11, 18) | 6 cases | |
| Middle Temp. Convolution (2, 3, 4, 6, 13, 19, 20) | 7 cases | |
| Combined (Superior & Middle) (4′, 5, 12, 16, 22, 23) | 6 cases | |
| Inferior Temp. Convolution—on inferior aspect (9) | 1 case | |
| Medial (insular) surface | 4 cases | |
| *Posterior 4 cm. Temporal Lobe* | | |
| Combined (Superior & Middle) | 1 case | |
| No focus (10, 15) | | 2 cases |

3′, 4′, 6′ indicate secondary procedures.

* Cases 3 and 6 were originally operated upon with the findings noted above. Because of recurrent clinical and EEG abnormalities, re-exploration was carried out 7 months later (3′ and 6′) to determine, if possible, the residual focus. In each case it was the superior temporal convolution. This observation encouraged more radical surgery in the future. Case 4 was only transiently benefited by the left-sided lobectomy, and, being a severe bilateral case, a similar procedure was done on the opposite side (4′).

or medially (adjacent to the insula). Spiking was occasionally seen in normal appearing cortex of the temporal pole, adjacent to a meningocortical scar. It has been our experience that *sleep* (Gibbs *et al.*[10,11,13]) is an efficient method of activating the seizure activity in psychomotor epilepsy. For this reason, metrazol or electrical stimulation were not used.

## RESULTS OF TEMPORAL LOBE SURGERY

*Mortality and Morbidity.* All 23 patients are living. Only 1 patient can be considered to be worse because of the surgery. Case 13 had a postoperative subdural hygroma, a peptic ulcer, and jaundice. Although he has had no seizures postoperatively, he is mentally retarded and debilitated because of the complications. In 1 patient (Case 11), who had arterial hypertension, an extradural hematoma formed postoperatively, but following evacuation of the hematoma he recovered and is now working. Cases 16 and 22 exhibited postoperative hyperthermia and evidence of aseptic meningitis. In both instances, the tip of the temporal horn of the lateral ventricle was involved in the lobectomy. Both have made full recoveries.

There have been no anesthetic complications, in spite of the prolonged procedures.

The symptoms following temporal lobectomy of the major side are described in detail by Nielsen.[23] The lesions in the 13 cases cited by him involve the auditory receptive cortex or structures of the middle and posterior temporal areas, functioning areas that we have assiduously avoided.

Neurologic deficits following anterior temporal lobectomy are surprisingly few. Sixteen of the operations were done on the dominant side. During the first 24–72 hours, the patients showed marked lethargy, similar to that following prefrontal lobotomy, but without urinary incontinence. Occasionally a mild verbal auditory agnosia was observed, but in no case did this persist more than 3 months. One patient (14), at the end of 6 months, shows a moderate anomia for which he is compensating quite well. Amusia or agnosia related to musical perception has not been noted in any of the patients, even transiently. There have been no instances of visual field defects or olfactory abnormalities postoperatively. A rather characteristic "tameness" is evident in most of these patients, in comparison with their preoperative states.

We have had only 1 patient in whom the condition was so severe that bilateral anterior temporal lobectomy was carried out. This young man (Case 4) has not been changed appreciably by the procedures, except that there is now an increased "hypermetamorphic impulse to action," loss of social consciousness and increased sexual interest—a modification of the results following bilateral temporal lobectomies in monkeys (Klüver and Bucy,[22] and Bucy[5]). His parents feel that the loss of viciousness compensates for the factors mentioned above. This patient will be reported in detail at a later date.

*Seizure, Mental, and Electroencephalographic Changes.* The original patient was operated upon on July 26, 1948; 15 patients were operated upon

during 1949 and the first week of 1950, and 7 patients since Jan. 25, 1950, the last being on May 20, 1950. Interestingly enough, recurrence of seizures has been within the first few weeks postoperatively in those patients who have not shown much improvement. The ultimate value of the surgical treatment in this series of cases must await a 5- or 10-year follow-up.

Twelve of the 23 patients have had no recurrence of psychomotor seizures, and there has been a definite reduction in the number of attacks in 9 other patients.

Twenty of the 23 patients also had either major or Jacksonian convulsions pre-operatively. Ten of these 20 patients have had no such attacks postoperatively, and there was an appreciable lessening in the number of attacks in 9 other patients.

Twelve of the 23 patients showed an absence of EEG spiking, and there was some improvement in the records of 8 other patients. Close correlation of clinical and EEG improvement was observed. Eight of the 23 patients were improved psychiatrically. The results as obtained to date are listed by patient in Table 4.

TABLE 4

*Effects of anterior temporal lobectomy*
*22 of 23 cases of psychomotor epilepsy**

| | |
|---|---|
| *Psychomotor Seizures* | |
| Stopped | —12 cases (1, 9, 12, 13, 14, 16, 18, 19, 20, 21, 22, 23) |
| Reduced | — 9 cases (3, 4, 5, 6, 7, 8, 10, 11, 17) |
| Same | — 1 case (2) |
| *Major and Jacksonian Seizures* (None pre-operatively in 11, 17, 22) | |
| Stopped | —10 cases (1, 9, 12, 14, 16, 18, 19, 20, 21, 23) |
| Reduced | — 9 cases (2, 3, 4, 5, 6, 7, 8, 10, 13) |
| Same | — 0 cases |
| *EEG Spiking* | |
| Stopped | —12 cases (1, 12, 13, 14, 16, 17, 18, 19, 20, 21, 22, 23) |
| Reduced | — 8 cases (3, 4, 5, 6, 7, 8, 9, 11) |
| Same | — 2 cases (2, 10) |
| *Psychiatrically* | |
| Better | — 8 cases (1, 2, 7, 9, 11, 12, 14, 19) |
| Same | —12 cases (3, 4, 6, 8, 10, 16, 17, 18, 20, 21, 22, 23) |
| Worse | — 2 cases (5, 13) |

* No resection was made in Case 15, status unchanged. No case of aggravation of clinical or EEG seizures.

## DISCUSSION

In evaluating this method of treatment, some interesting correlations are apparent. It is hoped that such analysis will improve the selection of cases and understanding of the techniques employed, but, at best, it can be considered as of tentative value.

I. *Seizure Patterns.* Among the 12 patients relieved of psychomotor attacks by anterior temporal lobectomy, the essential characteristics of the seizures were as follows:

*Case 1.* Hateful, suspicious, belligerent personality, with sudden attacks of mental confusion, sudden shouting, clumsiness, negativism, violence with tearing apar

of furniture and throwing objects, usually preceded by the expression: "Whoopee, here I go again."

*Case 9.* Mental confusion, with mumbling, singing, chewing, confused talking, negativism, easily angered if touched, becoming violent and assaultive.

*Case 12.* Abdominal pain, mental confusion, resistiveness, violence, occasional assaultiveness with shouting "I'll kill! I'll kill!"

*Case 13.* Mental confusion, followed by excitement, hysteria, leading to assaultiveness and violence.

*Case 14.* A sensation of strangeness and living out a dream, of floating, associated with hostility and assaultiveness.

*Case 16.* Confusion, incoherence, garrulousness, running, falling, followed by major convulsions.

*Case 18.* Confusion, running, combativeness for prolonged periods.

*Case 19.* Confusion, groping, abdominal distress, major convulsions.

*Case 20.* Mental confusion, fumbling, staring, smacking, tapping of the feet, groping, looking silly, twisting of the right arm, and a major convulsion.

*Case 21.* Mental confusion, running, jumping, violent swearing.

*Case 22.* Mental confusion, fullness of the head, far away sounds, buzzing, incoordination of movements.

*Case 23.* A sensation of strangeness, mental confusion, buzzing, stuttering, followed by convulsive movements of the right corner of the mouth, leading to a generalized seizure.

Among the 11 patients not completely relieved of psychomotor attacks by anterior temporal lobectomy, the essential characteristics of the seizures were similar to those above, with these additional symptoms:

*Case 2.* Psychotic, delusional, violent.

*Case 3.* Temper tantrums, rages, psychotic episodes.

*Case 4.* Intense fright, terror, temper tantrums ("like a monster").

*Case 5.* Tormenting illusions, religious delusions of damnation, suicidal.

*Case 6.* Severe temper outbursts, violence, religious fantaticism with intense anguish.

*Case 7.* Sudden mental confusion, throwing of objects, incoordination of movement, pushing, groping, searching, rubbing, undressing, laughing, crying, mumbling, setting objects on fire and taking medicine to excess.

*Case 8.* Psychotic and screaming.

*Case 10.* Violent anger, homicidal acts.

*Case 11.* Intense terror.

*Cases 15 and 17.* Intermittent psychoses, intense headaches and Demerol addiction.

II. *Age* of the patients, and *duration* of the psychomotor attacks at the time of surgery had relatively no correlation with the results of anterior temporal lobectomy.

Of the 12 patients having no psychomotor attacks postoperatively, the ages varied between 17–43 years, with the average duration between the onset of seizures and surgery being approximately 14 years. Of the group who had recurrence of attacks, the ages varied between 14–50 years, the average duration between the onset of seizures and surgery being approximately 9 years.

III. *Personality Type and Psychiatric Disorder.* Patients with psychomotor epilepsy and behavior marked by a rather consistent hostility (with associated affective change) have done well psychiatrically after anterior temporal lobectomy. On the other hand patients with (1) psychotic trends and (2) psychopathic trends, including addiction, have done poorly. It is felt that no definite psychiatric indications or contra-indications for surgery of this type should be laid down on the basis of our experience at the present time.

IV. *Trauma and Psychomotor Epilepsy.* A history of severe cranio-cerebral trauma preceding the onset of seizures of psychomotor type was obtained in 14 (1, 3, 9, 12, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23) of the 23 patients, with 11 of the 14 having no recurrence of seizures following anterior temporal lobectomy, as yet. Gross or microscopic pathology was found in all of these patients, except for Case 15 (no resection was made) and Case 17. Both of these patients have had recurrence of seizures.

Walker[40] has pointed out that the real frequency of convulsive seizures following brain trauma is difficult to assess. Although the incidence of epilepsy following open head wounds is said to vary from 4.5 per cent (Sargent)[36] to 45 per cent (Ascroft),[1] with the incidence following closed wounds around 3.5 per cent (Russell),[34] yet the true severity of the lesion is essentially the extent of the involvement of the cortex. Contusions and lacerations are particularly likely to occur when the cerebrum is flung forcibly against the irregularities, including the sharp edges of the sphenoid bones (Rowbotham),[32] creating injuries to the poles of the frontal or temporal lobes. It has been pointed out (Table I, Walker)[40] that seizures occur most frequently if the lesion is located in or near the central sulcus, and next most frequently if it is in the temporal region.

V. *Serial Electroencephalography and Electrocorticography.* The characteristic EEG findings of localized cerebral damage (slow activity with spikes or sharp waves), as described by Gibbs, *et al.*,[17] Jasper and Kershman,[20] and Jasper and Penfield[21] were observed in our post-traumatic cases. Spiking only was observed in the focal cases in which no pathological changes could be found. These focal alterations were surprisingly constant. Contralateral activity was noted in 9 cases.

Sugar *et al.*[37] have utilized the method of physiological neuronography (serial strychnization and EEG studies) in the Macaca mulatta to demonstrate a lack of extensive efferent connections in the temporal pole in the superior temporal plane, although it does fire into neighboring regions and is connected to its homologue (area 38) of the opposite side by tracts that traverse the anterior portion of the middle of the corpus callosum. The major connections of the acoustic receptive cortex, behind the inferior extremity of the central sulcus, were found to be to the frontal eye field (area 8), the frontoparietal "face" area (6b, 44, 43, 1), the visual association areas (18, 19), other portions of the temporal lobe (areas 21, 22, 37), and across the posterior fourth of the corpus callosum to the homologous cortex of the opposite side.

Anterior temporal lobectomy (anterior to the acoustic receptive cortex) resulted in complete elimination of the spike discharges in 12 cases (1, 12, 13, 14, 16, 17, 18, 19, 20, 21, 22, 23). It is of interest to note that Case 1 had bilateral involvement, left being maximal. Case 6 had the focus on the right (non-dominant side), and all of the others were on the left (dominant side). Only 1 of these patients has had a recurrence of psychomotor attacks, and these are considerably modified (Case 6). The 4 other patients who have not had recurrence of psychomotor attacks following surgery had unilateral foci in 2 cases (9: right; 20: left) and bilateral foci in 2 cases (7: right maximal; 16: left maximal). EEG spiking, in a reduced degree, is still present in these patients. Recurrence of clinical abnormalities is considered to be more likely in these 4 patients than in those with normal EEG studies.

VI. *Anterior Temporal Lobectomy, Blood Pressure, Pulse and Respirations.* Chapman, Livingston and Poppen[6] have recently reported elevation of blood pressure by electrical stimulation of the tips of the temporal lobes and have made suggestions of possible connections between the tips of the temporal lobes and the hypothalamus which might mediate the blood pressure responses.

The blood pressure, pulse and respiratory rates of each patient were observed pre-operatively, during the craniotomy, with particular reference to the time of manipulation or dissection of the temporal pole, and post-operatively. Only 1 patient (Case 11) had arterial hypertension; this was not affected by anterior temporal lobectomy on the dominant side. One patient (Case 17) showed no blood pressure fluctuations pre-operatively, nor during a trephination and depth electrode study on Jan. 24, 1950. At craniotomy, on Feb. 1, 1950, a sudden hypertension (128/78 to 242/104) developed as the dura was opened. It became apparent that an extensive subcortical hematoma had formed in the right anterior temporal area, secondary to the procedure of the preceding week. Fluctuations of blood pressure continued until the procedure was completed, with normal recordings since that date. Studies have failed to reveal a pheochromocytoma. The mechanism of the sudden hypertension is not certain. The remainder of the patients (21 patients, 26 temporal lobe procedures) have demonstrated no significant variations of pulse, respirations, or blood pressure.

VII. *Clinical Results and Surgical Method.* Cortical excisions have been made in the treatment of focal epilepsy since the era of modern neurosurgery, beginning with Sir Victor Horsley in 1886.[18] The clinical results of such procedures are surprisingly good in carefully selected patients, with elimination of seizures in nearly one-half of reported cases and improvement in others (Sachs,[35] Rowe and Watts,[33] Furlow,[9] Tönnis,[38] German,[12] Pilcher,[31] Penfield and Erickson,[29] Olivecrona,[24] Voris,[39] Elvidge,[7] Penfield and Steelman[30] and Walker[40]).

With the development of electrocorticography the role of the scar in the production of epilepsy has become less emphasized, and that of the adjacent cortex stressed (Walker,[40] Penfield[28]). "This epileptogenic zone, not

the scar, is the focus responsible for the epilepsy" (Walker[40]). It is this focus, if definitely demarcated, that has been removed in our cases, even in the absence of visible pathology.

It appears that the clinical results following surgery for focal epilepsy of psychomotor type may depend on the amount of the anterior temporal lobe that is removed. In the original cases of Bailey and Gibbs,[2,3] a temporal lobotomy only was done, and later gyrectomies, with better clinical results observed in the cases in which more radical excision had been done.

In our series, the surgical procedures and clinical results were as follows:

*Case 1.* The anterior 3 cm. of the left (dominant) temporal lobe was removed on July 26, 1948, with no recurrence of seizures and with remarkable general improvement, to this date.

Extensive gyrectomies were carried out in the next 5 cases (May 9, 1949, to May 20, 1949):

*Case 2.* Anterior 3.5 cm. of the middle temporal convolution. There has been both clinical and EEG recurrence of seizure abnormalities. It is planned to re-explore and study the cause of the failure, and, if indicated, to carry out anterior temporal lobectomy.

*Case 3.* Anterior 4.5 cm. of the middle temporal convolution, and the anterior 3.5 cm. of the inferior temporal convolution. There was a recurrence of both clinical and EEG seizure activity. Re-exploration and electrocorticography, 9 months after the first procedure, indicated that the cause of the failure was a spike focus in the superior temporal convolution. Anterior temporal lobectomy, exposing a clean insular surface, of 4.5 cm. of the temporal pole, was carried out, resulting in general improvement, elimination of attacks of psychomotor type, reduction of convulsions, elimination of EEG spiking on the operated side, with the appearance of mild spike abnormalities in the homologous area of the opposite side.

*Case 4.* Anterior 5 cm. of the middle and inferior convolutions on the dominant (left) side. There was recurrence of clinical and EEG abnormalities postoperatively, with intensification of the focus on the non-dominant side (right anterior temporal). A radical anterior temporal lobectomy (anterior 5 cm.) was carried out. This patient has lost his viciousness; still has mild spiking on the gyrectomized side, but none on the lobectomized side; shows a reduction of psychomotor attacks; a continuation of convulsions and increased compulsiveness to action; exhibits loss of fear and increase in sexual interest. There is a definite similarity to the findings of Klüver and Bucy[22] following bilateral temporal lobectomy in rhesus monkeys.

*Case 5.* Anterior 4 cm. of right temporal lobe, leaving the cortex next to the insula. A reduction in clinical and EEG abnormalities resulted, without any benefit regarding severe psychotic trends.

*Case 6.* Anterior 6 cm. of the middle and inferior temporal convolutions of the right temporal lobe. A recurrence of clinical and EEG seizure activity, and of psychotic trends, developed. Eight months later, re-exploration and electrocorticography revealed active spiking from the first temporal convolution. Anterior temporal lobectomy (anterior 6 cm.), cleanly exposing the insula, resulted in reduction of EEG and psychomotor seizure abnormalities, but had no effect on the psychotic abnormalities.

Anterior temporal lobectomies were done in the remainder of the patients, 17 cases, after May 21, 1949, because no significant neurologic deficits had

been observed in unilateral operations, and evaluation of the failures at re-operation had indicated involvement of the adjacent tissue of the temporal tip. The resections have varied from 3.5 cm. to 5 cm. from the temporal pole (Fig. 5).

## SUMMARY

1. A preliminary report is made regarding focal epilepsy of psychomotor type with reference to the effects of extensive gyrectomies and anterior temporal lobectomies.

2. Clinical, electroencephalographic, and electrocorticographic studies show close correlation, indicating localization in the anterior temporal areas.

3. Gross or microscopic pathology was found in association with the electrographic disturbances in the anterior portion of the affected temporal lobe in 14 of the 23 patients. Tissue was not removed in 1 case. In general, these patients were benefited more by surgery than those in whom no pathology was found.

4. In selected cases of psychomotor epilepsy, temporal lobectomy, anterior to the acoustic receptive cortex, appears to be more effective than lobotomy or gyrectomy.

5. The neurologic deficits following anterior temporal lobectomy in this series are described.

6. Of 23 patients, 12 have had no psychomotor seizures postoperatively.

7. The effects of anterior temporal lobectomy on seizures, EEG and mental status are reported. Clinical elements that appear to be associated with favorable and unfavorable results are discussed.

8. Whereas many years must elapse prior to formulation of definite conclusions, it appears that radical excision offers hope for selected patients who have definite clinical and electrographic localization and whose attacks are not controlled by medications.

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## REFERENCES

1. Ascroft, P. B. Traumatic epilepsy after gunshot wounds of the head. *Brit. med. J.*, 1941, *1:* 739–744.
2. Bailey, P., and Gibbs, F. A. A preliminary report on therapeutic results of temporal lobotomy for psychomotor epilepsy. Read before the Central Association of Electroencephalographers, Chicago, Nov. 27–28, 1948.
3. Bailey, P., and Gibbs, F. A. The surgical treatment of psychomotor epilepsy. *J. Amer. med. Ass.*, 1951, *145:* 365–370.
4. Belinson, L. Electroencephalographic characteristics of institutionalized epileptics. *Amer. J. ment. Def.*, 1947, *52:* 9–15.
5. Bucy, P. C. The relationship of the temporal lobes to primate behavior. *Trans. Kansas City Acad. Med.*, 1939–41, 223–233.
6. Chapman, W. P., Livingston, K. E., and Poppen, J. L. Effect upon blood pressure of electrical stimulation of tips of temporal lobes in man. *J. Neurophysiol.*, 1950, *13:* 65–71.
7. Elvidge, A. R. The post-traumatic convulsive and allied states. In: *Injuries of the skull, brain*

*and spinal cord. Neuro-psychiatric, surgical, and medico-legal aspects.* S. Brock, Ed. Baltimore: Williams & Wilkins Co., 1943, 2nd ed., ix, 616 pp. (see pp. 223–262).

8. Foerster, O., and Penfield, W. The structural basis of traumatic epilepsy and results of radical operation. *Brain*, 1930, *53:* 99–119.
9. Furlow, L. T. Subpial resection of the cortex for focal epilepsy. Further observations. *J. Amer. med. Ass.*, 1938, *111:* 2092–2095.
10. Fuster, B., Gibbs, E. L., and Gibbs, F. A. Caracteres electroencefalograficos de la epilepsia psicomotriz. Foco de espiculas negativas de localizacion temporal anterior en el E.E.G. obtenido durante el sueño normal o inducido con diferentes drogas. *Neurocirugia*, 1948, *4:* 287–301.
11. Fuster, B., Gibbs, E. L., and Gibbs, F. A. Pentothal sleep as an aid to the diagnosis and localization of seizure discharges of the psychomotor type. *Dis. nerv. System*, 1948, *9:* 199–202.
12. German, W. J. Epileptogenic cortical scars. Results of surgical removal. *Arch. Neurol. Psychiat., Chicago*, 1939, *41:* 73–81.
13. Gibbs, E. L., and Gibbs, F. A. Diagnostic and localizing value of electroencephalographic studies in sleep. *Res. Publ. Ass. nerv. ment. Dis.*, 1947, *26:* 366–376.
14. Gibbs, E. L., Gibbs, F. A., and Fuster, B. Psychomotor epilepsy. *Arch. Neurol. Psychiat., Chicago*, 1948, *60:* 331–339.
15. Gibbs, F. A. Psychomotor epilepsy; a syndrome of the anterior temporal lobe. Ictal and non-ictal psychiatric disorders in temporal lobe epilepsy. (In press, *J. nerv. ment. Dis.*)
16. Gibbs, F. A., Gibbs, E. L., and Lennox, W. G. Epilepsy: a paroxysmal cerebral dysrhythmia. *Brain*, 1937, *60:* 377–388.
17. Gibbs, F. A., Wegner, W. R., and Gibbs, E. L. The electroencephalogram in post-traumatic epilepsy. *Amer. J. Psychiat.*, 1944, *100:* 738–749.
18. Horsley, V. The function of the so-called motor area of the brain. *Brit. med. J.*, 1909, *2:* 125–132.
19. Jackson, J. H. In: *Selected writings of John Hughlings Jackson. Vol. 1, On epilepsy and epileptiform convulsions.* J. Taylor, Ed. London: Hodder & Stoughton, 1931, 500 pp.
20. Jasper, H. H., and Kershman, J. Electroencephalography. *Progress Neurol. Psychiat.*, 1946, *1:* 372–397.
21. Jasper, H., and Penfield, W. Electroencephalograms in post-traumatic epilepsy. Pre-operative and post-operative studies. *Amer. J. Psychiat.*, 1943, *100:* 365–377.
22. Klüver, H., and Bucy, P. C. Preliminary analysis of functions of the temporal lobes in monkeys. *Arch. Neurol. Psychiat., Chicago*, 1939, *42:* 979–1000.
23. Nielsen, J. M. Agnosia, apraxia, aphasia. Their value in cerebral localization. *New York: P. B. Hoeber, Inc.*, 1946, 2nd ed., x, 292 pp.
24. Olivecrona, H. Corticomeningeal scars in traumatic epilepsy. Localization by pneumographic examination of the subdural space. *Arch. Neurol. Psychiat., Chicago*, 1941, *45:* 666–671.
25. Penfield, W. The mechanism of cicatricial contraction in the brain. *Brain*, 1927, *50:* 499–517.
26. Penfield, W. Epilepsy and surgical therapy. *Arch. Neurol. Psychiat., Chicago*, 1936, *36:* 449–484.
27. Penfield, W. Classification of the epilepsies. *Arch. Neurol. Psychiat., Chicago*, 1948, *60:* 107–118.
28. Penfield, W. Cited in editorial: Surgical treatment of focal epilepsy. *J. Amer. med. Ass.*, 1949, *141:* 604–605.
29. Penfield, W., and Erickson, T. C. Epilepsy and cerebral localization. A study of the mechanism, treatment and prevention of epileptic seizures. *Springfield, Ill.: Charles C Thomas*, 1941, x, 623 pp.
30. Penfield, W., and Steelman, H. The treatment of focal epilepsy by cortical excision. *Ann. Surg.*, 1947, *126:* 740–761.
31. Pilcher, C. Surgical aspects of the epilepsy problem. *South. Surg.*, 1940, *9:* 301–311.
32. Rowbotham, G. F. Acute injuries of the head. Their diagnosis, treatment, complications and sequels. *Edinburgh: E. & S. Livingstone*, 1942, 288 pp.
33. Rowe, S. N., and Watts, J. W. Traumatic epilepsy with cortical scar. Diagnosis and results of operation in 20 cases. *Med. Ann. D. C.*, 1936, *5:* 298–301.
34. Russell, W. R. Medical aspects of head injury. *Brit. med. J.*, 1942, *2:* 521–523.
35. Sachs, E. The subpial resection of the cortex in the treatment of Jacksonian epilepsy (Horsley operation) with observations on areas 4 and 6. *Brain*, 1935, *58:* 492–503.
36. Sargent, P. Some observations on epilepsy. *Brain*, 1921, *44:* 312–328.
37. Sugar, O., French, J. D., and Chusid, J. G. Corticocortical connections of the superior surface of the temporal operculum in the monkey (Macaca mulatta). *J. Neurophysiol.*, 1948, *11:* 175–184.
38. Tönnis, W. Die Behandlung der posttraumatischen Spätepilepsie. *Zbl. Neurochir.*, 1939, *4:* 240–241.
39. Voris, H. C. Surgical treatment of epilepsy. *Dis. nerv. System*, 1943, *4:* 363–368.
40. Walker, A. E. Posttraumatic epilepsy. *Springfield, Ill.: Charles C Thomas*, 1949, viii, 86 pp.

# MÉNIÈRE'S DISEASE AND ITS SURGICAL TREATMENT

## REPORT OF 300 CASES*

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OLIVECRONA[17,18] in 1943 described all cases of Ménière's disease observed in the Neurosurgical Clinic of Serafimerlasarettet from 1930 to December 31, 1942, a total of 160 cases. This paper is a continuation of the previous work, including all cases observed up to December 31, 1949. The total has now increased to 300, averaging 20 cases a year. Of these patients, 254 were operated upon. This represents 2.5 per cent of all surgical operations performed at this Clinic.

Ménière's disease is a symptom-complex characterized by sudden attacks of vertigo usually accompanied by nausea and vomiting, unilateral reduction of hearing, and tinnitus. The cause is probably irritation of the acoustic nerve. The exact localization of an abnormal stimulus is not yet known but the most likely situation is in the terminal receptors. A similar symptom-complex may be caused by any space-occupying lesion around the eighth nerve; in such a case we prefer to call it Ménière's syndrome. Frequency and duration of attacks are very variable, a peculiarity of the disease being long periods of remission. Examination almost always reveals defect of the acoustic nerve, more marked in the cochlear than in the vestibular branch.

The space-occupying lesions that may cause a Ménière's syndrome are acoustic neurinomas, other cerebellopontine angle tumors, and aneurysms of the vertebral artery or, less frequently, of the posterior choroidal artery. These lesions, however, simulate Ménière's disease only at their onset, because during the course of the disease other symptoms develop, such as of a lesion of other cranial nerves and often of the cerebellum, while in Ménière's disease only the acoustic nerve is affected. Only in cases of vertebral aneurysm may Ménière's syndrome be simulated for a long time (Olivecrona). Processes affecting the ear (otitis media with extensive perforation of the tympanum, otosclerosis) may also exhibit symptoms of Ménière's syndrome.

*Sex and Age.* The disease is more common in men. Of our patients, 186 were men and 114 women. The onset is usually between the ages of 31 and 55 years; 211 of our cases (70 per cent) came within this group. The youngest patient was 13 years of age, the oldest 72. The age distribution appears in Fig. 1.

*Laterality.* In 147 patients the disease was on the right side, and in 142 on the left. In 11 patients it was difficult to determine the affected side.

* The surgical results of the same material were presented at the "Giornate Mediche Internazionali," Verona, Italy, July 20–30, 1950.

† Chief: Professor H. Olivecrona.

Occasionally a bilateral acoustic examination revealed no abnormalities, so that if the patient did not have a definite unilateral tinnitus it was impossible to determine the side of the disease. Bilateral Ménière's disease does occur, and was found in 7 of our patients (2.3 per cent). Dandy[4,5] found a rather higher percentage (10 per cent).

*Predisposing Factors.* (a) *Trauma.* Previous trauma was ascertained in 37 of our patients. Dandy[5] considered trauma of no importance. This has not been our experience. In the majority of cases trauma is important only because it calls attention to a pre-existing process, but some of our cases present interesting considerations. In 1 patient (No. 60, History: 233.38) unilateral tinnitus and deafness developed immediately after a cranial trauma. Ten years later he had typical attacks of Ménière's syndrome. Operation

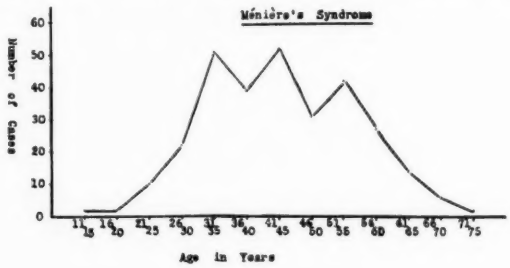


FIG. 1

revealed an arachnoiditis of the cerebellopontine angle, bridling the nerves and vessels (a branch of the anterior inferior cerebellar artery was very adherent to the eighth nerve).

(b) *Otitis.* Ear infections affecting only the diseased side, or both sides, occurred in 26 instances. In several of our cases an earlier otitis media, particularly if accompanied by a defect of the tympanum, without doubt played an important role. One patient (No. 17, History: 2752.35) had bilateral otitis media with extensive perforation of the tympana. Examination of the vestibular function was impossible because even gentle blowing into the external ear, especially on the right side, caused nausea and typical dizziness. The right side was most affected and section of the right vestibular branch was performed. Several years later, however, the patient again had attacks of dizziness, probably due to irritation of the left acoustic nerve. This case was diagnosed as bilateral Ménière's disease.

*Blood Pressure.* A rise in blood pressure is often considered to be the cause of dizziness. The average blood pressure in 270 patients was systolic 138, and diastolic 82, corresponding almost to that found by Crowe[3] in 68 patients, systolic 137, and diastolic 83. Only in a few instances did the pressure rise to nearly 200. We therefore do not consider that blood pressure plays any important role.

*Symptomatology.* As stated previously, Ménière's disease is characterized

by unilateral deafness, tinnitus, and typical attacks of vertigo accompanied by nausea and vomiting. The average *duration* of symptoms at the time of admission to hospital was from 6 to 7 years. The shortest period was 4 months, the longest 30 years.

The *first* symptom in the 300 patients in this series is shown in Table 1.

TABLE 1

| | No. of Pts. | Percentage |
|---|---|---|
| Dizziness | 175 | 58.2 |
| Tinnitus | 49 | 16.3 |
| Deafness | 28 | 9.3 |
| Tinnitus and deafness | 41 | 14.0 |
| Dizziness and tinnitus | 4 | 1.3 |
| Dizziness and deafness | 1 | 0.3 |
| Dizziness, deafness and tinnitus | 2 | 0.6 |

Table 1 shows that dizziness was usually the earliest symptom. However, it is quite probable that the disease began with a slight deafness often revealed by a casual examination. Dandy[5] states that deafness is usually present when the first attack appears, and Wright[20] maintains that the first symptoms are not pertinent to the vestibule, but to the cochlea, probably due to the presence of the "vascular area" in the cochlea, which secretes endolymph. Examination further shows that hearing is affected much more often than the vestibular function (see later).

In the majority of cases the three characteristic symptoms appear a short time apart, but often the first appears much earlier than the others. Table 2 shows the number of patients in our material in whom the first symptom appeared at least 3 years before the others.

TABLE 2

| | No. of Pts. |
|---|---|
| Dizziness | 20 |
| Tinnitus | 8 |
| Deafness | 10 |
| Tinnitus and deafness | 7 |

*Dizziness* is the main symptom. The attacks of vertigo are usually characteristic, and are referred to as Ménière's attacks. The frequency of the attacks is highly variable. They may occur several times in one day, or years apart. In some forms of Ménière's disease there may be mild and more or less permanent giddiness, with a tendency to recrudescence. We found 2 such cases in our material. In similar cases Crowe[3] considered it advisable to suspect an acoustic tumor. The duration of the attacks is also very variable. They may last for a few minutes, or for several days. We have found that the average attack lasts about 2 hours. Typical attacks of vertigo begin

suddenly. The patient must hold on to something to keep from falling. He feels that everything is spinning, often in one definite direction. This fact we were able to ascertain in 44 patients. In 23 patients the objects seemed to whirl towards the diseased side, in 21 towards the healthy side. This sign is therefore of no importance in determining the side of the lesion. Several patients felt the necessity of lying down on a certain side during the attacks to avoid the recurrence of dizziness, but this fact was also of no practical importance. Nausea, cold sweats, and diarrhea often occur, and are probably explained by a lowering of the blood pressure. In 2 instances there was loss of consciousness. In Crowe's material loss of consciousness occurred in 12.8 per cent of the patients. Vomiting is usually associated with dizziness and occurred in 70 per cent of our patients. It may occur several times during the same attack. The onset of deafness is insidious. It usually has a slowly progressive course and may result in complete deafness. Of our patients 43 (13 per cent) were completely deaf. Tinnitus may be constantly present or may disappear between attacks. It usually becomes worse just before an attack, and grows more intense during and after the attack. It does not disappear with complete deafness, and sometimes constitutes the warning *aura* of attacks of vertigo. The term "pseudo-Ménière's disease" is used to indicate characteristic attacks of vertigo without deafness and tinnitus. In such cases it is always difficult to determine the side of the disease, especially when the auditory and vestibular tests are completely normal. We had 2 such cases. In one, the patient vaguely remembered having had a slight unilateral tinnitus for a short time. Section of the vestibular branch of the acoustic nerve was performed on the affected side with good result. The other patient was not operated upon. In similar cases Dandy[6] advised bilateral section of the vestibular portion of the acoustic nerve. He sometimes performed the bilateral procedures at the same time, with satisfactory results. Bilateral operation usually causes disturbances of equilibrium, especially in the dark. Romberg's sign is positive. There is no ataxia, but inability to coordinate the movements of the eyes. Headache, usually of the frontal type, was present in about 30 per cent of our patients. Mygind and Dederding[15] found this symptom in a very high percentage of their patients, and attribute it to an accumulation of cerebrospinal fluid in the posterior cranial fossa. This phenomenon could also be due to changes in the hydrosaline metabolism causing a considerable retention of water.

*Pathological Anatomy.* This constitutes a rather unknown chapter. Hallpike and Cairns[10] (1938) examined the labyrinths of 2 patients with Ménière's disease who had died following operation. In both cases, in addition to signs of chronic otitis, they found gross dilatation of the membranous labryinth and degeneration of the organ of Corti and the vestibular receptors. According to them the dilatation of the labyrinth was due to increased endolymphatic tension which caused compression of the receptors and their subsequent degeneration. In another case of Ménière's disease, in which death was due to pneumonia, Berggren[2] and Gray were unable to find any

pathologic changes in either the labyrinth or the central nervous system. Berggren refutes the hypothesis of Winkler who, on the basis of animal experiments, maintains that lesions of the nuclei of Goll and Burdach may cause a disease similar to Ménière's syndrome. To this effect he cites a case of Stenwers in which complete degeneration of these nuclei was found, whilst the patient, when alive, had never had attacks of dizziness. The hypothesis that Ménière's disease is due to central lesions is difficult to accept because it is hard to understand how a metencephalic process can affect only the vestibular and cochlear nuclei, which do not even lie in close proximity, without causing any change in other adjacent structures. Sometimes dizziness persisted even after section of the vestibular nerve. This may suggest a central lesion, but is probably due to incomplete division of the vestibular nerve or to a bilateral affliction.

Histological examination of the acoustic nerve gave contradictory results. Dandy[5] consistently found signs of fibrosis, and maintained that the pathological stimulus is situated in the nerve trunk. Berggren[2] (2 cases), Crowe[3] (2 cases) and Furstenberg[8] (11 cases), on the other hand, never found any pathologic changes in the nerve removed at operation. Furthermore, mechanical stimulation with a dissector of both branches of the acoustic nerve in patients who had been locally anesthetized caused only slight nausea and, occasionally, vomiting, but never dizziness. In 1 patient the cochlear nerve was stimulated with faradic current without any effect. Wright[20] is of the opinion that the lesion is caused by dilatation of the labyrinth and chemical modification of the endolymph system.

Attention should also be given to the alterations in course of the anterior inferior cerebellar artery. This artery may pass either above the eighth nerve, between its two branches, or below the eighth and seventh nerves. In 1 patient McKenzie[13,14] found a small venous plexus above the acoustic nerve. He considered the anomalous course of the anterior inferior cerebellar artery to be one of the causes of Ménière's syndrome. Watt and McKillop[19] described the great variability in the course of this artery in relation to the acoustic nerve, and considered deafness in some patients, especially the older ones, to be due to sclerosis of the artery which, owing to its abnormal hardening and thickening, compresses the nerve. Dandy, in 20 per cent of 550 patients operated upon, found an encircling artery constricting the nerve, or a large artery lying on it. In several of our cases an artery was found lying close to the acoustic nerve, which appeared sometimes to be the internal auditory artery, and sometimes the anterior inferior cerebellar artery.

*Etiology.* The original hypothesis that Ménière's disease was due to an intralabyrinthine hemorrhage has always been the least acceptable. Not long ago Öhnell[16] again studied this hypothesis, and considered the possibility of a relationship between Ménière's disease and scurvy. He examined 87 patients, and found evidence of scurvy in 45 of them. A further 8 patients probably had scurvy; in the remaining 34 patients it was doubtful. From a

therapeutic point of view he appears to have obtained favorable results with the administration of vitamin C. Investigations in Macacus rhesus in which he produced artificial scurvy, did not permit any conclusions being drawn.

Nowadays the generally accepted hypotheses regarding the cause of Ménière's disease are: the allergic, the bacterial, and the disturbance of water metabolism. Mygind and Dederding[15] maintained that Ménière's disease is caused by a biochemical alteration of the endolymph. According to them an increase of sodium ions in the endolymph produces a considerable fluid retention and, thereby, dilatation of the membranous labyrinth. This concept is corroborated by the anatomo-pathological investigations of Hallpike and Cairns.[10] According to Furstenberg, Richardson and Lathrop,[9] sodium ions cause dizziness. In several of our cases we have tested Furstenberg's therapy, a diet excluding sodium chloride but with large doses of ammonium chloride, with fairly good results, but the material is too small to draw any conclusions.

The allergic hypothesis, held chiefly by Horton,[11] is based on a casual discovery. A patient with migraine and Ménière's disease who was being treated with histamine for the former condition, recovered not only from the migraine, but also from Ménière's disease.

The bacterial hypothesis advanced by Wright[20] suggests a focal infection in the internal ear as the true and only cause of Ménière's disease. According to Wright all other mechanism may be considered as determining the attack, but not the essential cause of the disease.

The hypothesis of an angiospastic origin of dizziness also deserves mention. During the examination of the fundus oculi in a patient, Berggren[1] noticed a sudden spasm of the arteries and pallor of the papilla. A few seconds later the patient had a typical attack of dizziness. Apparently the same phenomena have been observed in cases of migraine.

*Objective Findings.* Audiograms and vestibular tests were carried out. Neurologic studies and general examinations seldom reveal anything of note. Results from bilateral audiograms and vestibular tests in the majority of the 300 patients of this series are shown in Table 3.

Conclusions from these data are: (1) There is an obvious difference between the diseased and healthy side, although in 12 cases the findings were normal on both sides (7 of these patients were not operated upon, and in the other 5 patients the proper side for operation was determined only by the tinnitus. (2) Tinnitus does not disappear with complete deafness; 43 patients who were totally deaf stated they had tinnitus. (3) Complete absence of vestibular excitability does not preclude dizziness. (4) The hearing is affected more often than the vestibular function. This may support the hypothesis that auditory disturbances occur much earlier than vestibular dysfunction.

Nystagmus was observed in about 10 per cent of the patients, but was of no aid in determining the side of the disease. In McKenzie's[12] group of 12 patients, 5 had nystagmus; in 3 of them the gaze towards the side of the

lesion increased the nystagmus. In another patient nystagmus was visible only during gaze to the affected side. The last patient had nystagmus only during attacks of vertigo and it was then much more evident towards the side later ascertained as the side of the lesion.

*Diagnosis.* In the majority of cases no difficulties were encountered in diagnosing the nature of the disease. X-ray examination of the internal auditory meatus should always be carried out. Encephalography is indicated in all cases in which a pontocerebellar tumor is suspected. These examinations were carried out in 30 patients, and in each case the findings were normal.

In only 1 case was an incipient papilloedema observed.

The diagnosis of Ménière's disease is based on the rather characteristic

TABLE 3

| | Diseased side | | Healthy side | |
|---|---|---|---|---|
| | No. of Pts. | Percentage | No. of Pts. | Percentage |
| Hearing | | | | |
| Complete deafness | 43 | 13 | 1 | 0.3 |
| Considerably decreased | 178 | 61 | 10 | 3 |
| Slightly decreased | 54 | 20 | 37 | 12.3 |
| Normal | 20 | 7 | 243 | 84.4 |
| Vestibular excitability | | | | |
| Absent | 20 | 7 | 0 | 0 |
| Considerably reduced | 73 | 25.5 | 4 | 1.3 |
| Slightly reduced | 70 | 24.5 | 29 | 9.7 |
| Normal | 128 | 43 | 259 | 89 |

history, the auditory and vestibular tests, the negative result of the neurologic examination (careful study of the trigeminal sensibility and corneal reflex, and facial motility), the X-ray findings and the encephalography.

## SURGICAL TREATMENT

Ménière's disease can be treated either medically or surgically. It is not our intention in this work to deal with the medical therapy. Surgical treatment is indicated in (1) all patients who have not improved on medical treatment and (2) patients whose working capacity is impaired due to the severity of the symptoms. The operation is contraindicated in patients who show progressive improvement with increasingly low periods of remission.

Various operative procedures are carried out for the relief of the symptoms. The operation may be performed on the labyrinth or on the nerve trunk, but the former is now seldom done. The method employed in this Clinic consists of section of either the entire acoustic nerve or only its vestibular branch. Dandy[4] in 1928, was the first to perform section of the acoustic nerve, and in 1931 McKenzie[13] the first to section only the vestibular branch.

In the present series 254 patients were operated upon. In 27 of them the

eighth nerve was completely divided, and in 226 only its vestibular branch. In 1 patient the posterior cranial fossa was explored and the acoustic nerve freed from adhesions, but not sectioned. In the first 11 patients operated upon during the years 1931 to 1936 the entire acoustic nerve was cut. Since 1936, however, only the vestibular branch of the eighth nerve has been cut, complete section being done only when the patients were totally deaf on the diseased side. In a few instances the nerve had to be completely divided to arrest accidental hemorrhage.

FIG. 2

*Operative Technic.* The patient is placed in face-down position and the head fixed with strips of adhesive tape (Fig. 2). The table is adapted with lateral supports so that it may be tilted around its long axle. During operation the table can be tilted this way, whereby a good exposure of the cerebellopontine angle is assured.

Local anesthesia was almost invariably employed, but in a few instances avertin was administered rectally.

The skin incision is best described by Fig. 3.

FIG. 3

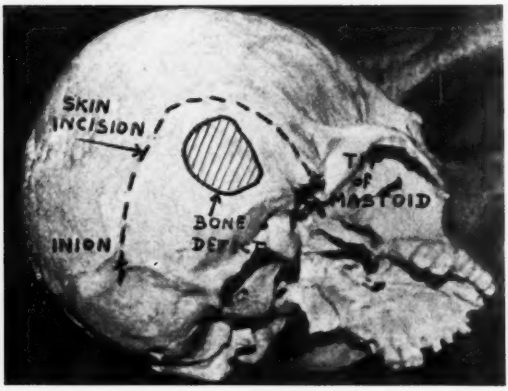


FIG. 4

The bone defect is made as high and as far lateral as possible. The defect must be made as small as possible (Fig. 4), with a maximum diameter of 2–3 cm. Small bone defects lessen danger of postoperative extradural hematoma. Operation is easier if the bone defect is so far lateral as to expose the

medial margin of the sigmoid sinus. Sometimes the mastoid cells are unavoidably opened, in which case they are injected with penicillin and plugged with surgical wax.

A straight lateral margin to the bone defect is advisable, so that the dural flap may be turned back on it, providing maximum exposure (Fig. 5). Complete bone hemostasis must be obtained before the dura is opened. The dura is opened by a T-shaped incision, seen in Fig. 5. At this stage the lateral cistern is opened, to further facilitate the operation. The fluid in the cistern having been drained, it is now possible to explore the cerebellopontine angle. The cerebellum is retracted medially and the acoustic and facial nerves are identified. The facial nerve is situated ventrally, and is usually hidden by the acoustic nerve. As is well known, about 1 cm. from the internal auditory meatus, the cochlear branch is located caudally and the vestibular branch cranially. Sometimes, owing to rotation of the nerve, the cochlear branch is directed dorsally and the vestibular ventrally. The farther one comes from the internal auditory meatus, the greater is the distance between the acoustic and facial nerves. As a rule the cochlear and vestibular branches of the acoustic nerve are distinctly separate. Dandy[7] reports a case in which the two branches were completely detached. Sometimes, however, the acoustic nerve appears as a single structure, and it is then difficult to see the line of division. If the patient is totally deaf on the side of operation the nerve is any case completely divided. If the deafness is only partial, only the cranial half of the nerve is cut. Very frequently, as already pointed out under the heading of pathologic anatomy, small arteries are found lying close to the acoustic nerve. Occasionally an artery is situated between the acoustic and facial nerves, completely hidden by the former. The artery can therefore be damaged during section of the nerve or the vestibular branch. The resulting hemorrhage can be very troublesome, and to control the bleeding it may be necessary to apply silver clips to the cochlear and facial nerves.

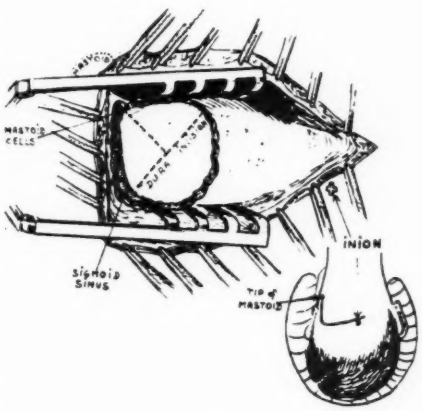


FIG. 5

The vestibular branch of the nerve, after being freed, should be lifted with a small blunt hook and divided with a small knife (Fig. 6). Dividing the vestibular nerve with a hook is not to be recommended because it is easy to damage the small arteries, and sometimes the facial nerve itself. It is very important that the function of the facial nerve be continuously observed throughout the operation. If during section of the vestibular branch

a sudden and complete facial paralysis is observed, accidental division of the facial nerve has most probably occurred. This can be verified by electrical stimulation of the nerve. In the event of the nerve being divided an attempt at anastomosis must immediately be made. Facial paralysis which appears a few hours or a few days after the operation is due to secondary causes, and regeneration of the nerve takes place within 6 months.

In retracting the cerebellum great care must be taken to avoid damaging the veins that run from the cerebellum to the dural sinus.

Having obtained complete hemostasis, the incision in the dura is closed with interrupted silk sutures. Any small defects in the dura are covered with fibrin or gelatine foam. The wound is then closed in anatomic layers. The muscles must be firmly and accurately sutured to prevent leakage of cerebrospinal fluid and formation of cysts.

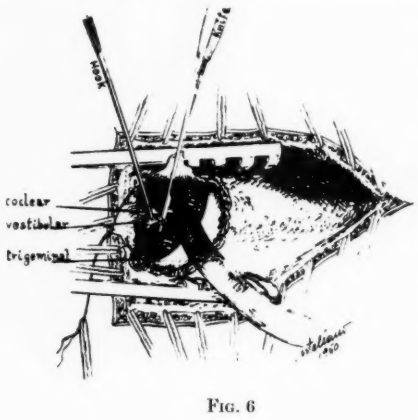


FIG. 6

As a rule, during the first 4 to 5 days after operation, the patient suffers from severe dizziness, vomiting, diplopia and headache, but these symptoms are transient and quickly disappear.

*Complications.* There were no operative deaths. The only complications were facial paralysis and extradural hematomas. Temporary facial paralysis was observed in 14 of our patients and permanent paralysis in 2 cases.* In a 3rd case the facial nerve was accidentally severed, but was satisfactorily repaired by a graft from the saphenous nerve, held in place with fibrinogen and thrombin. This procedure gave a satisfactory result, and 2 years after operation only a slight facial weakness was noticeable.

Extradural hematomas occurred in 5 instances. The symptomatology is well known. A few hours or 1–2 days after operation the patient begins to be dazed and does not reply to questions. Usually the blood pressure is raised and the pulse rate is decreased. In 1 patient there was simultaneously an extradural and an intracerebellar hematoma, which recurred three times. A hemorrhagic diathesis was finally discovered, the patient was given large doses of vitamins K and C, and recovered satisfactorily.

*Results.* The postoperative observation period in this series varies from

* In 1 case the internal auditory artery was hidden along its entire length between the acoustic and facial nerves. During section of the vestibular nerve, hemorrhage necessitated the use of silver clips, which resulted in injury to the cochlear branch and facial nerve. Facial paralysis followed immediately and was permanent. In another case the facial nerve was injured by a hook, probably because the division of the vestibular branch by the hook was made too near the porus acusticus, where the facial and acoustic nerves lie in close proximity. Anastomosis according to Dott was attempted, but failed on account of necrosis of graft. Facial-spinal anastomosis was then performed, but the facial paralysis did not improve.

a few months to 19 years. The patients keep us informed yearly as regards their state of health, and sometimes attend the Clinic for control examinations. During this period only 3 patients have died, the cause of death in each case being due to irrelevant diseases.

After section of the vestibular branch it is no longer possible to stimulate the vestibule, and nystagmus towards the non-affected side is always observed. In 7 patients the vestibule could still be stimulated by injecting a great quantity of cold water, but in no case was dizziness aroused. Complete freedom from dizziness was obtained in all cases except 8, in 7 of these probably due to a bilateral affliction and in 1 presumably due to incomplete section of the vestibular fibers. In this last-mentioned patient the attacks became less frequent, but did not disappear. In no case was bilateral operation performed. The majority of the 27 patients in whom the acoustic nerve was completely sectioned were totally deaf. Of the 226 patients in whom only the vestibular branch was divided, 46 became totally deaf. In 26 patients the hearing deteriorated, but in the majority of cases it was the same as before operation. In only 5 cases was there improvement in hearing after operation. Our percentage (2 per cent), therefore, is much lower than that of Crowe (20 per cent). The majority of our patients have been examined on discharge, 1–2 weeks after operation. The tinnitus was influenced by the extent of the operation. In 4 (15 per cent) of the 27 patients in whom complete section of the acoustic nerve was performed, the tinnitus improved, in 3 of them disappearing completely. In only 5 (2.2 per cent) of the 226 patients in whom only the vestibular branch was sectioned, did the tinnitus improve. In 2 of these 5 the tinnitus disappeared completely. Dandy[5] found improvement of the tinnitus in 50 per cent of his patients, a fact which surprises us. We maintain that the tinnitus seldom disappears. Probably, however, section of the cochlear branch would cause disappearance of tinnitus more often.

## SUMMARY

A series of 300 cases of Ménière's disease is presented with an account of etiology, pathological anatomy, symptomatology, objective findings, detailed operative procedure, and follow-up. There were 254 patients submitted to operation. In 27 complete section of the acoustic nerve was performed. In 226 only the vestibular branch was divided. In 1 the nerve was freed from adhesions, but not sectioned.

Complete freedom from dizziness was obtained in all patients except 8; 7 of these 8 patients had bilateral Ménière's disease. Tinnitus rarely disappeared. There was no operative mortality. Facial paralysis occurred in 16 cases, transient in 14, and permanent in 2. Postoperative extradural hematomas occurred in 5 patients, in 1 of them also an intracerebellar hematoma. Follow-up periods varied from a few months to 19 years.

## REFERENCES

1. Berggren, S. Die operative Behandlung der Ménièreschen Krankheit. *Hals-Nasen-Ohrenarzt*, 1941, *32*: 77–88.

2. Berggren, S. Anatomische Untersuchungen über die Ménièresche Krankheit. *Acta oto-laryng., Stockh.*, 1942, *30:* 104–109.
3. Crowe, S. J. Ménière's disease. A study based on examinations made before and after an intracranial division of the vestibular nerve. *Medicine*, 1938, *17:* 1–36.
4. Dandy, W. E. Ménière's disease. Its diagnosis and a method of treatment. *Arch. Surg., Chicago*, 1928, *16:* 1127–1152.
5. Dandy, W. E. Ménière's disease. Symptoms, objective findings and treatment in forty-two cases. *Arch. Otolaryng., Chicago*, 1934, *20:* 1–30.
6. Dandy, W. E. The treatment of so-called pseudo-Ménière's disease. *Johns Hopk. Hosp. Bull.*, 1934, *55:* 232–239.
7. Dandy, W. E. The surgical treatment of Ménière's disease. *Surg. Gynec. Obstet.*, 1941, *72:* 421–425.
8. Furstenberg, A. C., Lashmet, F. H., and Lathrop, F. Ménière's symptom complex: medical treatment. *Ann. Otol., etc., St. Louis*, 1934, *43:* 1035–1046.
9. Furstenberg, A. C., Richardson, G., and Lathrop, F. D. Ménière's disease. Addenda to medical therapy. *Arch. Otolaryng., Chicago*, 1941, *34:* 1083–1092.
10. Hallpike, C. S., and Cairns, H. Observations on the pathology of Ménière's syndrome. *J. Laryng.*, 1938, *53:* 625–655.
11. Horton, B. T. The use of histamine in Ménière's disease. *Surg. Gynec. Obstet.*, 1941, *72:* 417–420.
12. McKenzie, D. Nystagmus during the Ménière attack. *J. Laryng.*, 1924, *39:* 322–323.
13. McKenzie, K. G. Intracranial division of the vestibular portion of the auditory nerve for intractable vertigo. With two case reports. *Trans. Acad. Med., Toronto*, 1932–33, *14*.
14. McKenzie, K. G. Intracranial division of the vestibular portion of the auditory nerve for Ménière's disease. *Canad. med. Ass. J.*, 1936, *34:* 369–381.
15. Mygind, S. H., and Dederding, D. The significance of water metabolism in general pathology as demonstrated by experiments on the ear. *Acta oto-laryng., Stockh.*, 1932, *17:* 424–466.
16. Öhnell, H. Scorbutic vertigo. *Acta oto-laryng., Stockh.*, 1944, suppl. 58, 46 pp.
17. Olivecrona, H. Die chirurgische Behandlung der Ménièreschen Krankheit. *Münch. med. Wschr.*, 1943, *90:* 466–469.
18. Olivecrona, H. Om Ménières sjukdom och dess kirurgiska behandling. *Nord. Med.*, 1943, *19:* 1463–1466.
19. Watt, J. C., and McKillop, A. N. Relation of arteries to roots of nerves in posterior cranial fossa in man. *Arch. Surg., Chicago*, 1935, *30:* 336–345.
20. Wright, A. J. Ménière's disease—a critical review. *Proc. roy. Soc. Med.*, 1946, *39:* 809–810.

# METASTATIC HYPERNEPHROMA OF THE BRAIN FROM A NEUROSURGICAL POINT OF VIEW

## A REPORT OF 19 CASES

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IN NEUROSURGERY the question arises from time to time as to the advisability of operating upon a patient with cerebral metastasis. To take an example: a patient with a history of having been operated upon for hypernephroma shows clinical manifestations of brain tumor. The tumor being in all probability a metastasis, the efficacy of surgical intervention is questioned.

In the present report some aspects of this theme, illustrated by earlier reports from the literature and the material collected from the Neurosurgical Clinic of Serafimerlasarettet, will be given.

*Frequency of Brain Metastasis.* The problems of metastatic lesions in the brain have been referred to by many authors. Opinions regarding the frequency of brain metastasis differ widely. Statistical analyses of large general autopsy materials have been published (Krasting,[16] Rau,[19] Rudershausen,[20] Gutting[14]). The relation of brain metastasis to the total number of intracranial tumors was estimated by Rudershausen[20] to be 18 per cent and by Gutting[14] to be 25 per cent. In a total of 28,831 autopsies Gutting found 243 primary brain tumors and 85 brain metastases.

On the other hand, in a neurosurgical material the frequency of brain metastasis is low, approximately 5 per cent, ranging from 3.4 in some series to 7 per cent in others (Cushing,[6] Christensen,[4] Davis[8] and others).

Cushing[6] stated, with regard to metastatic intracranial tumors, that "their relative scarcity in the series of brain tumors as a whole, viz. 4.2 per cent, by no means represents their true clinical incidence, for we refrain when possible from accepting patients with obvious intracranial metastasis since so little can be done for them by surgical procedures."

Metastatic brain tumors have been discussed from a neurosurgical point of view by Grant,[13] Meagher and Eisenhardt,[17] Cushing,[6] Bailey,[2] Christensen,[4] Dandy,[7] Davis,[8] Elvidge,[10] Oldberg,[18] and others.

Grant[13] inter alia, expresses the general opinion as regards the hopelessness of surgical treatment in these cases in his statement: "Surgery, whether radical or palliative, is of no ultimate benefit to these patients insofar as prolongation of life is concerned. But surgical intervention for the relief of intracranial pressure is frequently indicated and may go far toward relieving suffering in the last few months of life."

* Director: Professor Herbert Olivecrona.

This pessimistic attitude is also presented in recent monographs on intracranial tumors (Dandy,[7] Bailey[2]).

*Frequency of Metastatic Hypernephroma of Brain.* A review of the literature on the occurrence of metastatic hypernephroma of the brain shows that mostly isolated cases have been reported (Gerwer,[12] Chukry,[5] Foerster,[11] Elmer,[9] Valdes[21]).

Augstein[1] collected from the works of 30 different authors a total of 9 cases of cerebral metastasis from 141 cases of verified hypernephroma. Even Cushing[6] in his material of 2000 cases of intracranial tumors had only 85 metastatic brain lesions: 56 carcinomas, 20 sarcomas, and 5 hypernephromas. Christensen,[4] in a series of 2023 operations for intracranial tumors, found metastasis in 82 cases (3.9 per cent), of which 6 were metastatic hypernephromas. Davis[8] reported a total of 805 intracranial tumors of which 57 (7 per cent) were metastatic and among them were 6 hypernephromas. Elvidge and Baldwin[10] found 3 cases of metastatic hypernephromas in 88 cases of metastatic involvement of the central nervous system. Gutting,[14] in his large autopsy material, had 85 cases of brain metastases, of which 8 were hypernephromas.

Thus the frequency of metastatic hypernephroma in a material of intracranial metastatic lesions appears to range from 3 to 10 per cent; the latter figure is probably the more reliable.

*Frequency of Metastasis from Primary Hypernephroma to Intracranial Cavity.* Exact figures are difficult to obtain. Gutting[14] reports 77 cases of hypernephroma, of which 8 (10 per cent) metastasized to the brain. Brunner[3] found metastasis to the brain to be as frequent as 16 per cent. Hannemann's[15] figure was somewhat lower.

*Survival Period in Cases of Metastatic Hypernephroma of Brain.* Information concerning the survival period is sparse. Reference to this will be made later but, as already mentioned, the general view appears to be pessimistic. The survival period after clinical manifestations of brain tumor was considered to be on an average only a few months, with a maximum of 6 months, regardless of surgical intervention (Grant,[13] Meagher and Eisenhardt,[17] Davis,[8] Elvidge and Baldwin[10]).

A more positive neurosurgical treatment, however, with removal of the metastatic lesions, has been advocated; Oldberg[18] points out that "there are naturally certain criteria which are not to be disregarded in deciding an active surgical course. The most important of these is the question of multiplicity of metastases." He reports cases of metastatic carcinoma of the brain in which the survival period following intracranial operation is longer than in previously reported cases; 2 years in 1 case after extirpation of a parieto-occipital tumor arising from carcinoma of the breast; in another, alleviation of symptoms for almost 3 years after extirpation of a tumor from a carcinoma of the lung.

Concerning the hypernephromas Cushing[6] had the impression that metastases of this nature are more favourable than those from a primary sarcoma

or carcinoma. He points out that ordinarily metastases to the brain are multiple; but adds: "Nevertheless one may occasionally encounter what appear to be solitary tumours sometimes of comparatively large size; and the fact that patients . . . have had unexpectedly long postoperative survival periods [6 years in 1 case, 3 and 2 years in 2 other cases] after removal of a metastatic lesion brings a certain gleam of hope to what surgically is an otherwise most gloomy subject."

## MATERIAL

The present material consists of 19 cases from the Neurosurgical Clinic of Serafimerlasarettet. During the 25-year-period from 1922 to 1946, a total of 3256 patients with brain tumor were admitted. There were 112 cases of metastases (3.4 per cent), of which 15 were hypernephromas (about 0.5 per cent of the total tumor material and 13.4 per cent of the metastatic lesions). During the last 4 years 4 additional patients have been operated upon, thus making the total of 19 cases of metastatic hypernephroma of the brain reported here.

Of these 19 patients, 17 were male and 2 were female. Their ages ranged from 36 to 70 years, the average age being 50 years. Ten of the patients were between 50 and 60 years of age; 3 were young, aged only 36 years. Seventeen have died; 2 are still alive. A summary of the 19 cases is given in Table 1.

*How long may a patient live with a metastatic hypernephroma of the brain?* It will be seen that some patients are living several years after the appearance of clinical manifestations of brain tumor; 1 is still alive more than 14 years later. Among the patients who have died 1 lived for $6\frac{1}{2}$ years, 2 for more than 4 years, 1 for more than 3 years, 2 for more than 2 years and 2 for 1 year after manifestation of cerebral symptoms. The other 10 patients had fairly short periods of life, from 2 to 11 months. The survival periods after onset of intracranial symptoms and after intracranial operation are shown in Table 2.

The following cases exemplify the variation of symptoms and course of hypernephroma metastasis to the brain.

*Case 1.* J.Nr. 152/36. J.A., a 51-year-old farmer, had a right nephrectomy for malignant hypernephroma in 1934. One year later, there developed headache, impaired vision, and slight motor ataxia. In 1936 he was operated on for a tumor in the right cerebellar hemisphere, and a growth the size of a hen's egg was removed (Fig. 1A). This proved to be a metastatic hypernephroma (Fig. 1B). The postoperative course was uneventful, but owing to highly choked discs, about 5D, optic atrophy developed with reduction in vision.

The patient *is still living, 14 years after the brain operation*, and is in tolerably good health. He has slight ataxia and impaired vision, but is able to do light manual work, read papers and write letters clearly and distinctly.

*Case 2.* J.Nr. 533/44. T.N., a 52-year-old man, had a left nephrectomy for hypernephroma in 1940. In 1944, 4 years later, he showed neurologic symptoms, headache, impaired vision, and a slight right-sided hemiparesis. Enucleation of a

## TABLE 1

*19 cases of metastatic hypernephroma of the brain*

| Cases | | | Operations | Metastasis in | | Period from Onset of Intracranial Symptoms | | Survival Period After Brain Metastasis Operation |
|---|---|---|---|---|---|---|---|---|
| No. | Sex | Age | | Brain | Body | to Brain Metastasis Operation | to Death or to Present Date | |
| 1. J.A. 152/36 | M | 51 | 1. Renal dx. 2. Cerebellar | Solitary at op. | Living | 8 mos. | 14 yrs., 8 mos. (living) | 14 yrs. (living) |
| 2. T.N. 533/44 | M | 52 | 1. Renal sin. 2. Frontal lobe sin. | Solitary at op. (No autopsy) | No autopsy | 4 mos. | 4 yrs., 10 mos. | 4 yrs., 6 mos. |
| 3. K.J. 1241/30 | M | 43 | Frontal lobe dx. | Big solitary at op. (No autopsy) | No autopsy | 5 yrs. | 6 yrs., 6 mos. | 1 yr., 6 mos. |
| 4. M.S. 182/46 | F | 58 | 1. Renal dx. 2. Parietal lobe sin. | Solitary at op. (No autopsy) | No autopsy | 2 yrs. | 3 yrs., 3 mos. | 1 yr., 3 mos. |
| 5. A.L. 1422/29 | M | 36 | Cerebellar | Solitary at op. (No autopsy) | No autopsy | 4 mos. | 1 yr., 6 mos. | 1 yr., 2 mos. |
| 6. M.Th. 2524/33 | F | 45 | 1. Renal sin. 2. Temporal lobe dx. | Solitary at op. (No autopsy) | Multiple pulmonary | 2 mos. | 1 yr. | 10 mos. |
| 7. Z.E. 963/46 | M | 36 | 1. Renal dx. 2. Parietal lobe dx. | Solitary at op. (No autopsy) | No autopsy | 3 mos. | 11 mos. | 8 mos. |
| 8. B.L. 1013/46 | M | 47 | Fossae med. et post. bas. cranii (non-radical) | "Carpet-like" at op. (No autopsy) | No autopsy | 1 yr., 4 mos. | 2 yrs. | 8 mos. |
| 9. K.R. 570/48 | M | 55 | 1. Renal sin. 2. Hypophysial region | Solitary at op. (No autopsy) | Multiple | 4 mos. | 10 mos. | 6 mos. |
| 10. J.A. 980/22 | M | 59 | Cerebral hemisph. dx. | Multiple | No autopsy | 1½ mos. | 6 mos. | 4½ mos. |
| 11. A.M. 603/49 | M | 52 | 1. Renal dx. 2. Frontal lobe dx. | Solitary at op. (No autopsy) | No autopsy (metastasis in nephrectomy scar) | 1 mo. | 3½ mos. | 2½ mos. |
| 12. A.P. 201/50 | M | 58 | Pariet.-occip. region dx. | Solitary at op. | Living | 2 yrs. | 2 yrs., 2 mos. (living) | 2 mos. (living) |
| 13. J.O. 793/41 | M | 52 | Parietal lobe sin. (Autopsy: Renal sin.) | Big solitary | Multiple | 4 yrs. | ca. 4 yrs. | 16 d. |
| 14. K.F. 1180/44 | M | 70 | Cerebellar (Autopsy: Renal bilat.) | Solitary | None | 6 mos. | 6½ mos. | 14 d. |
| 15. E.S. 938/30 | M | 50 | Temporal lobe sin. | 2 solitary | No autopsy | 3 mos. | 3 mos. | 5 d. |
| 16. H.K. 1166/44 | M | 48 | Parietal lobe sin. (Autopsy: Renal sin.) | Solitary | Multiple | 2 mos. | 2 mos. | 1 d. |
| 17. K.R. 519/36 | M | 57 | Cerebellar (Autopsy: Suprarenal sin.) | Solitary | None | 9 mos. | 9 mos. | 1 d. |
| 18. K.K. 857/39 | M | 41 | No op. (Autopsy: Region pontis +renal dx.) | Solitary | Multiple pulmonary | 2 mos. | 2 mos. | No operation |
| 19. J.S. 491/51 | M | 36 | No op. (Autopsy: Multiple cerebral +suprarenal sin.) | Multiple | Multiple | 2 mos. | 2 mos. | No operation |

TABLE 2

*Survival periods*

| Years | After Onset of Intracranial Symptoms (Cases) | After Brain Metastasis Operation (Cases) |
|---|---|---|
| $<\frac{1}{2}$ | 5 | 8 (+2 not operated) |
| $\frac{1}{2}$–1 | 5 | 4 |
| 1–2 | 2 | 3 |
| 2–3 | 2 | — |
| 3–4 | 1 | — |
| 4–5 | 2 | 1 |
| 5–10 | 1 | — |
| 10–15 | 1 (living) | 1 (living) |

tumor in the left frontal lobe was performed the same year. The tumor, a well-defined greyish-red growth, the size of a hazel nut, proved to be metastatic hypernephroma on microscopic examination (Fig. 2).

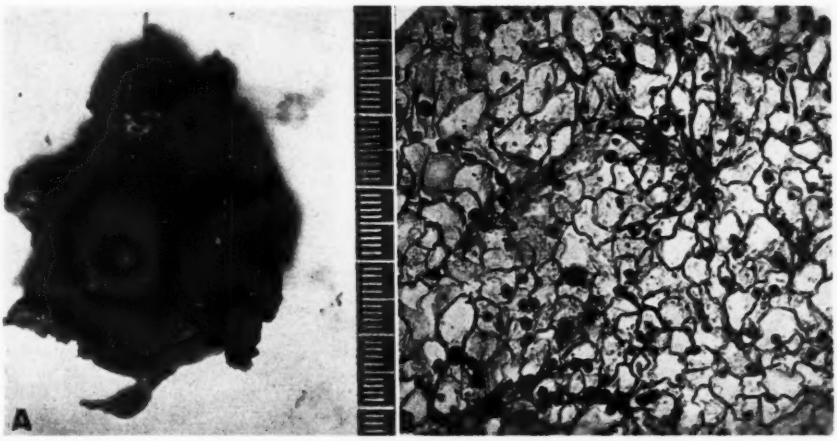


FIG. 1. *Case 1.* (A) Metastatic hypernephroma removed from cerebellar hemisphere. Patient is still alive 14 years after operation. (B) Photomicrograph of tumor. Ladewig stain, ×280.

The postoperative course was uneventful, but due to choked discs of 6 D., a permanent amaurosis developed. In 1947, 3 years later, the patient was still blind, but otherwise in good health. In 1949, at the age of 58, he died of pneumonia. Autopsy was not performed as he died at home.

*Comment.* The remarkable fact in Case 2 is the interval of 4 years between nephrectomy and appearance of neurological manifestations. The survival period was $4\frac{1}{2}$ years from the brain operation, and 9 years from the nephrectomy for hypernephroma.

*Case 3.* J.Nr. 1241/30. K.J., a 43-year-old farmer, had had epileptic fits of left-

sided Jacksonian type for 5 years before admission. During the last year he suffered headache, reduced vision with rapid progress to amaurosis, and left-sided hemiparesis. Ventriculography revealed a big right-sided frontal tumor, which at operation was found to be cystic and of grey-red colour. Pathological diagnosis: Hypernephroma. It was unfortunately not radically removed because of its malignant appearance.

The patient was psychically unaltered and survived for 1½ years after operation. As he died at home, an autopsy was not performed.

A rare operative finding of a metastatic hypernephroma in a meningioma is illustrated in Case 6.

*Case 6.* J.Nr. 2524/33. M.T., a 45-year-old woman, had been operated upon 3

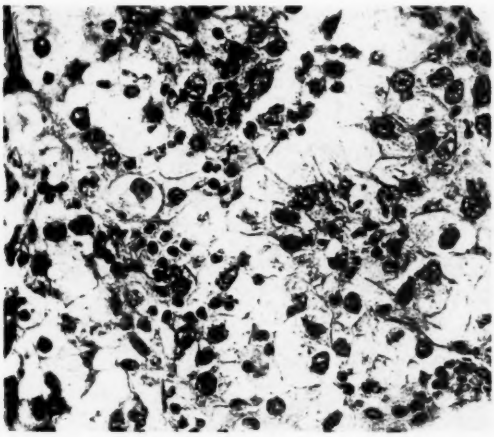

FIG. 2. *Case 2.* Photomicrograph of metastatic hypernephroma of frontal lobe. Patient survived for 4½ years after extirpation. Weigert-van Gieson stain, ×310.

FIG. 3. *Case 6.* Meningioma of right Sylvian region invaded by a metastatic hypernephroma (see Fig. 4). Patient survived for 10 months after operation.

years previously for a hypernephroma of the left kidney. Two months before admission she was taken ill with left-sided Jacksonian fits beginning in the face, disturbance of speech, and attacks of paresthesias and diminished sensitivity in the left arm. On examination, bilateral choked discs and a slight left-sided facial palsy were found. Roentgenogram of the skull disclosed increased vascularity on the right side above pterion; the right middle meningeal artery was considerably wider than the left. Ventriculography showed a tumor in the right Sylvian fissure. The operation revealed a tumor half the size of an orange, very vascular and adherent to the dura. Macroscopically it was like a meningioma (Fig. 3). On microscopic examination it was found to be *metastatic hypernephroma in a typical meningioma* (Fig. 4).

The immediate postoperative course was uneventful, but 10 months later the patient died, probably from pulmonary metastases (which had been observed in the roentgenogram 10 months previously).

*Case 17.* J.Nr. 519/36. K.R., a 57-year-old merchant, had had balance disturbance and psychic deterioration for about 9 months. On examination, findings were

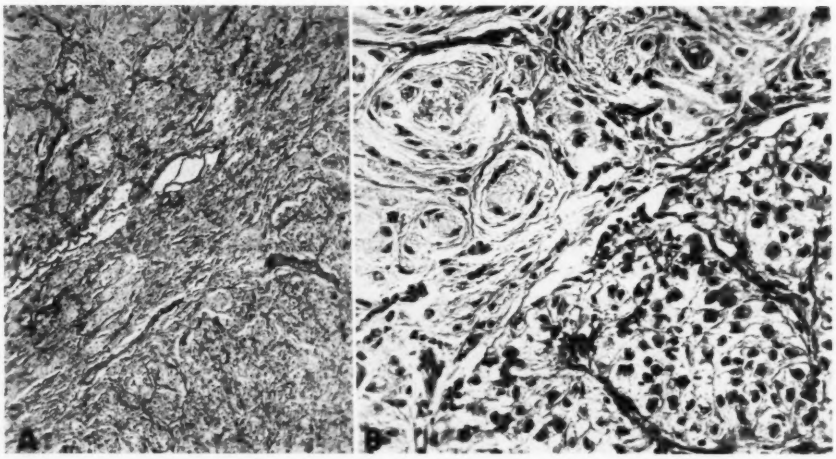

FIG. 4. *Case 6.* Photomicrographs of tumor in Fig. 3. (A) Ladewig stain, ×45. (B) Hematoxylin-eosin stain, ×200. In upper left-hand corner, a typical meningioma with characteristic whorl formation. In lower right-hand corner, the metastatic hypernephroma with clear cells.

bilateral dysmetria and rigidity in the lower extremities and increased intracranial pressure with choked discs. Ventriculography showed a right-sided cerebellar tumor.

The patient became unconscious immediately before the operation, which in

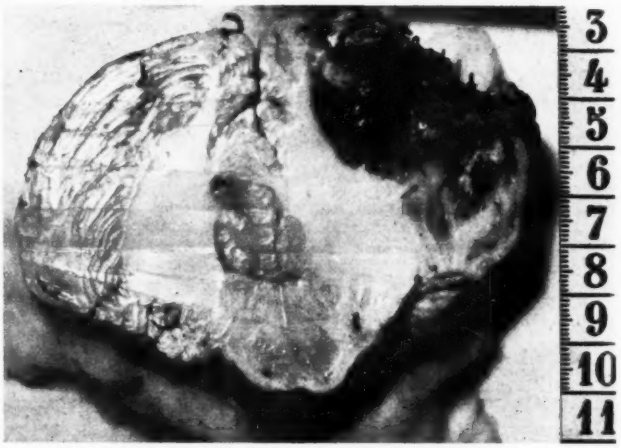


FIG. 5. *Case 17.* A single cerebellar metastatic lesion from a hypernephroma of the suprarenal gland without any body metastases.

itself was performed without difficulty. An isolated tumor, the size of a walnut, was easily extirpated, but the patient died the following day. Autopsy showed a tumor of the left suprarenal gland *without any metastases elsewhere in the body.*

*Comment.* In the brain of Case 17, there was only this single cerebellar metastasis (Fig. 5) and thus the case represents a good one from a neurosurgical point of view, even if it had a fatal outcome.

An example of general body and multiple brain metastases is shown in Case 19.

*Case 19.* J.Nr. 491/37. J.A.S., a 36-year-old labourer, had a history of left-sided hemiparesis and slow cerebration for 2 months. Autopsy revealed hypernephroma of the left suprarenal gland with general metastases to the liver and both lungs, and multiple metastases to the brain. Fig. 6 shows a section of one metastatic tumor the size of a goose's egg and two somewhat smaller.

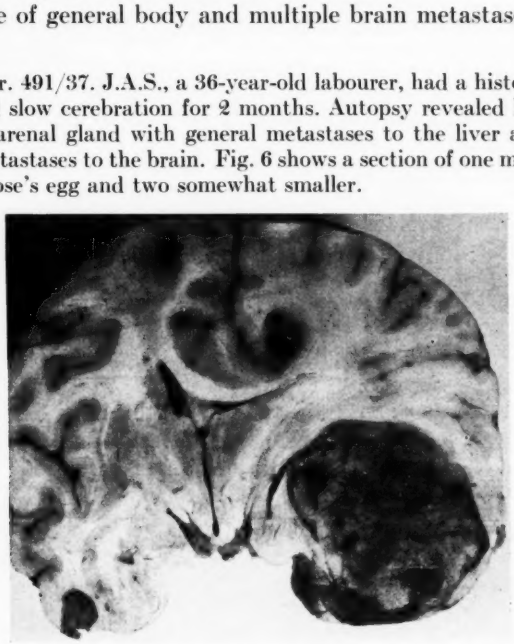

FIG. 6. *Case 19.* Coronal section of brain. The patient had multiple body and brain metastases.

## DISCUSSION

To evaluate neurosurgical treatment for brain metastases, the pathological nature and clinical features characteristic of these tumors must be investigated together with their operability. The chances of radical operation are measured by the postoperative period of survival.

*Pathology of Metastatic Hypernephroma of Brain.* It must be remembered that only about 10 per cent of all hypernephromas metastasize to the brain (Gutting[14]).

*The mode of metastasis* is generally accepted to be that of the blood stream. At autopsy tumor masses are often found invading the inferior vena cava and, passing the lungs, by way of the carotid or vertebral arteries, proceeding to the brain. The migrating hypernephroma cells pass through the lungs, and in some cases we found roentgenographic evidence of pulmonary metastases; a fermentative lysis of the metastatic cells probably takes place in the lungs and this phenomenon would explain cerebral metastasis without any pulmonary metastatic lesions.

Other modes of metastasis might be possible, e.g. via the subarachnoid space in the lower thoracic region and by the spinal fluid to the brain. In Case 8 this might have occurred, because at operation a peculiar type of metastatic lesion was found spread over the bottom of the middle and posterior fossa cranii and involving cranial nerves (cf. "carcinomatous and sarcomatous pachymeningitis").

The *rapidity with which metastatic tumors grow* is an important factor in determining whether a lesion is benign or malignant. Metastatic hypernephromas appear to grow very slowly. Christensen[4] pointed out that in some cases of malignant tumor, such as hypernephroma and melanoma, intracranial metastases may occur as late as 4 years or more after removal of the primary tumor. In Case 2 in this series an interval of 4 years elapsed between the nephrectomy and the appearance of neurological symptoms. The metastatic tumor was, in this case, situated in the frontal lobe, which is a comparatively silent zone, and was only the size of a hazel nut. In 4 of the other cases more than 1 year, and even 2 to 3 years elapsed between removal of the primary tumor and the appearance of cerebral symptoms (Table 3).

*Clinical Features.* The clinical picture of the metastatic lesion is that of a brain tumor and it is not possible to make a diagnosis of metastasis from the case history. Not infrequently *Jacksonian* fits have been the only symptom for several years (Case 3).

Foerster[11] reported the case of a patient who had had epileptic seizures of focal type for 8 years. At operation a metastatic hypernephroma of the brain, the size of a walnut, was found. The patient recovered and returned to work. He was still alive 1 year after the operation and was free from symptoms.

Bailey[2] pointed out that the symptoms of metastatic cerebral tumor do not differ essentially from those of primary cerebral tumors. But he has noted, as more or less characteristic, the intensity of the headache and mental confusion; there is often tremendous edema of the brain so that the intracranial tension is out of all proportion to the mass of neoplasm present. When signs of general metastasis are found, e.g. to the lungs, no real benefit is derived from operating upon a cerebral metastatic tumor. Bailey advocated that middle-aged or elderly individuals who suddenly develop a psychosis, or focal cerebral symptoms, not obviously luetic or vascular in origin, should have a roentgenogram taken of the lungs.

In Case 6 of my material, a metastatic hypernephroma in a meningioma was extirpated and the patient survived for 10 months, in spite of roentgenographic evidence of pulmonary metastases.

A considerably increased *sedimentation rate* is sometimes a sign of malignancy, and may be an aid in diagnosis and prognosis. In this material the sedimentation rate ranged from 1 to 88 mm./hour. In 8 cases it was <15 mm./hour. Only 4 patients had greatly increased sedimentation rates, ranging from 40 to 88 mm./hour, and these had multiple metastases in the body. It is difficult to draw any definite conclusions regarding the relationship

of sedimentation rate to the type and extent of metastases. A considerably increased sedimentation rate of 50 mm./hour or more is always suggestive of malignancy, but a low sedimentation rate does not speak against it. For example, 1 of our patients (Case 6) had multiple metastatic hypernephromas in the lungs and a sedimentation rate of only 4 mm./hour.

*Survival Period* (Table 2). If the length of life is to be considered in relation to the pathological findings, certain factors must be taken into account (1) Primary tumor, and metastases in the body; (2) Brain metastasis and its pathogenicity: the type of tumor, solitary or multiple, its location in the brain, and rapidity of growth. The neurological symptoms and operability of the tumor depend on these factors.

(1) *Primary Tumor.* If the patient is to have a good chance of survival for a fairly long time, there must be no metastases in the body. In 7 of our cases the primary tumor was diagnosed, and nephrectomy performed; in 5 cases there was an interval of more than 1 year before neurological symptoms developed (Table 3).

TABLE 3

*Brain metastasis from hypernephroma*
*7 cases in which the primary kidney tumor had been removed before the brain operation*

| Cases | | | Period from Nephrectomy | | | Period from Onset of Intracranial Symptoms | | Survival Period After Brain Metastasis Operation |
|---|---|---|---|---|---|---|---|---|
| No. | Sex | Age (Years) | to Onset of Intracranial Symptoms | to Brain Metastasis Operation | to Present Date or Death | to Brain Metastasis Operation | to Present Date or Death | |
| 1. | M | 51 | 1 yr. | 1 yr., 8 mos. | 15 yrs., 8 mos. (living) | 8 mos. | 14 yrs., 8 mos. (living) | 14 yrs. (living) |
| 2. | M | 52 | 4 yrs. | 4 yrs., 4 mos. | 8 yrs., 10 mos. | 4 mos. | 4 yrs., 10 mos. | 4 yrs., 6 mos. |
| 4. | F | 58 | 2 yrs. | 4 yrs. | 5 yrs., 3 mos. | 2 yrs. | 3 yrs., 3 mos. | 1 yr., 3 mos. |
| 6. | F | 45 | 3 yrs. | 3 yrs., 2 mos. | 4 yrs. | 2 mos. | 1 yr. | 10 mos. |
| 7. | M | 36 | 1 yr. | 1 yr., 3 mos. | 1 yr., 11 mos. | 3 mos. | 11 mos. | 8 mos. |
| 9. | M | 55 | 2 mos. | 6½ mos. | 1 yr., ½ mo. | 4 mos. | 10 mos. | 6 mos. |
| 11. | M | 52 | 4 mos. | 5 mos. | 7½ mos. | 1 mo. | 3½ mos. | 2½ mos. |

If it can be presumed that a primary tumor has been removed, the indications for neurosurgical intervention are stronger than if the primary tumor is unknown.

A case reported by Christensen[4] supports this view. A man who 9 years earlier had had a nephrectomy performed for hypernephroma was operated upon for an intracranial tumor. Histological examination of the removed tumor revealed a typical picture of hypernephroma. Three years after the brain operation the patient was alive, free from symptoms, and back at full work.

Cushing[6] mentioned a very interesting case in which "an easily enucleable 51-gram tumour was successfully removed from the left supramarginal gyrus of a [patient] who had previously shown a global aphasia. A complete recovery followed. . . . The tumour was diagnosed as a hypernephroma. . . . Owing to a recurrence of symptoms seven months later a second operation was performed, . . . when a precisely similar 42-gram tumour was removed from

the same situation as before . . . with complete recovery . . . . He remained symptom-free and led a normal active life for five years." A pulmonary lesion and apparent metastases to the bones were then disclosed and the patient died in another hospital without a postmortem examination.

(2) *Brain Metastasis.* If this is solitary, its removal is possible. Technically, the metastatic hypernephromas in this material have been easily enucleated. The brain operation itself, therefore, is comparatively easy, if the tumor is satisfactorily located. With modern methods of diagnosis, ventriculography combined with angiography, we are technically in a better position now than we were before.

*Operative Mortality* (Table 1). Of the 19 patients reported, 17 have been operated upon, with 5 fatalities within 20 days of the operation, making a 30 per cent operative mortality. The 2 patients not operated upon were in too poor a condition for surgical intervention, and also had multiple body metastases.

*Single or Multiple Brain Metastases.* In most of the patients operated upon well defined, easily extirpative tumors were found at the operation. There is certainly in these patients a possibility of metastases to other parts of the brain. At the operation, however, one had, from a clinical point of view, fairly localized neurological findings to deal with, a fact that might contradict multiplicity.

FIG. 7. *Case 15.* Section of brain showing two cerebral metastatic tumors, one larger and one smaller. The patient was a 50-year-old mason with symptoms of right-sided hemiparesis and aphasia of sensory type. Operation disclosed a deeply situated tumor in the left temporal lobe. Death occurred 5 days after operation.

In the brain material examined post mortem, consisting of 8 cases, a solitary tumor was found in 5 cases, and in 1 case, two tumors lying close together (Fig. 7).

In 1 case there were clearly multiple brain metastases with diffuse location; there was one very large tumor which seemed to be older, and there were several smaller ones (Fig. 6).

Thus the brain metastases found at operation seemed in 15 cases to be of a solitary type. Of the 8 cases examined post mortem, the brain in 5 cases showed only a single metastasis.

*Postoperative Survival Period.* Finally, a few words may be said concerning the general health and working capacity of the patients after operation.

Often patients obtain relief of the very troublesome headache. In some patients there is a surprising improvement in general health, and in a few instances the patient returns to an active life.

Unfortunately there is often a diminution of vision because of highly choked discs; in some cases there is even total amaurosis postoperatively. One patient (Case 2) had a postoperative survival period of 4½ years and was quite well otherwise. Thus an early diagnosis and suitable treatment are important in order to escape the very serious consequences of edema of the brain usually caused by the metastasis.

Both the previously reported cases and some of my own cases in which there has been a long survival period (my Case 1, still alive, 14 years after removal of a metastatic hypernephroma of the brain) speak in favour of more active neurosurgical treatment for brain metastases.

## SUMMARY

1. A neurosurgical material of 19 cases of metastatic hypernephroma of the brain is presented.

2. The frequency of hypernephroma among the metastatic brain tumors is about 13 per cent.

3. Metastasis to the brain appears, in most cases, to be solitary. A rare case of a metastatic hypernephroma in a meningioma is also reported (Case 6).

4. Patients can live for several years after extirpation of metastatic hypernephroma of the brain; in 1 case the patient is still alive 14 years after the brain operation (Case 1).

5. The prognosis appears to be most favorable in those cases in which the primary tumor in the body has been diagnosed earlier and removed, e.g. by nephrectomy, before symptoms manifesting cerebral metastasis appear.

Therefore, attempts to carry out radical neurosurgical treatment appear to be justified in patients suffering from metastatic hypernephroma of the brain.

## REFERENCES

1. Augstein, E. Ueber Hypernephrommetastasen im Zentralnervensystem. *Arch. Psychiat. Nervenkr.*, 1921, *63:* 591–600.
2. Bailey, P. Intracranial tumors. *Springfield, Ill.: Charles C Thomas*, 1948, 2nd ed., xxiv, 478 pp.
3. Brunner, W. Über die Häufigkeit von Gehirnmetastasen bösartiger Geschwülste, besonders des primären Lungentumors, und ihre Bedeutung für die Klinik. *Z. ges. Neurol. Psychiat.*, 1936, *154:* 793–798.
4. Christensen, E. Intracranial carcinomatous metastases in a neurosurgical clinic. *Acta psychiat., Kbh.*, 1949, *24:* 353–361.
5. Chukry, I. Un cas de tumeur de Grawitz avec métastases cérébrales. *Encéphale*, 1934, *29:* 202–205.
6. Cushing, H. Intracranial tumours. Notes upon a series of two thousand verified cases with surgical-mortality percentages pertaining thereto. *Springfield, Ill.: Charles C Thomas*, 1932, xii, 150 pp.
7. Dandy, W. E. Surgery of the brain. *Hagerstown, Md.: W. F. Prior Co., Inc.*, 1945, 671+17 pp.
8. Davis, L. The principles of neurological surgery. *Philadelphia: Lea & Febiger*, 1946, 540 pp.
9. Elmer, A. W., Kedzierski, J., and Scheps, M. Ein Fall von Diabetes insipidus verursacht durch eine Metastase eines Hypernephroms im Zwischenhirn. *Wien. klin. Wschr.*, 1928, *41:* 591–594.
10. Elvidge, A. R., and Baldwin, M. Clinical analysis of eighty-eight cases of metastatic carcinoma

involving the central nervous system. With an outline of therapeutic principles. *J. Neurosurg.*, 1949, *6:* 495–502.

11. Foerster, O. Die Diagnostik und Behandlung der Geschwülste des Grosshirns. *Klin. Wschr.*, 1934, *13:* 1737–1742.
12. Gerwer, A. W. Über die Metastasen der Hypernephrome im Grosshirn. *Arch. Psychiat. Nervenkr.*, 1929, *88:* 345–357.
13. Grant, F. C. Concerning intracranial malignant metastases. Their frequency and the value of surgery in their treatment. *Ann. Surg.*, 1926, *84:* 635–646.
14. Gutting, J. Hirnmetastase und Primärtumor. (Diss.) *Düsseldorf: Nolte*, 1940, 14 pp.
15. Hannemann, W. Statistische Angabe über metastatische Hirntumoren. (Diss.) *Düsseldorf: Nolte*, 1937, 11 pp.
16. Krasting, K. Beitrag zur Statistik und Kasuistik metastatischer Tumoren, besonders der Carcinommetastasen im Zentralnervensystem (auf Grund von 12730 Sektionen der pathologisch-anatomischen Anstalt Basel). *Z. Krebsforsch.*, 1906, *4:* 315–379.
17. Meagher, R., and Eisenhardt, L. Intracranial carcinomatous metastases. With note on relation of carcinoma and tubercle. *Ann. Surg.*, 1931, *93:* 132–140.
18. Oldberg, E. Surgical considerations of carcinomatous metastases to the brain. *J. Amer. med. Ass.*, 1933, *101:* 1458–1461.
19. Rau, W. Eine vergleichende Statistik der in 5 Kriegsjahren (1914–1919) und 5 Friedensjahren (1909–1914) sezierten Fälle von Krebs und anderen malignen Tumoren am Pathologischen Institut des Stadtkrankenhauses Dresden-Friedrichstadt. *Z. Krebsforsch.*, 1921, *18:* 141–170.
20. Rudershausen, V. Über Häufigkeit und Art der Hirngeschwülste an Hand des Sektionsmaterials des Pathologischen Instituts Heidelberg. *Virchows Arch.*, 1932, *285:* 318–331.
21. Valdes, A. Ein Fall von hypernephroidem Gewächs mit riesenzelligen Metastasen im Gehirn. *Frankfurt Z. Path.*, 1929, *37:* 475–480.

# THE EXPERIMENTAL APPLICATION OF ULTRASONICS TO THE LOCALIZATION OF BRAIN TUMORS

## PRELIMINARY REPORT*

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THIS report concerns an experimental attempt to apply ultrasonic pulses to the localization of brain tumors. The purpose of these experiments was to examine the possibility of locating, at the time of surgery, subcortical neoplasms without the use of brain needles. The principle upon which the experiments were based is that high frequency sound waves, when driven through tissues, are believed to travel at a rate proportional to the tissue density and to the tissue elasticity. These sound waves are reflected by surfaces of density or elasticity change, known as interfaces, and echoes are produced. Depending upon the texture and thickness of the tissue through which the waves traverse, the time interval before reception of the echo varies. With these known data it was postulated that by measuring this time interval, when ultrasonic pulses were sent through normal brain tissue, the presence of an underlying subcortical neoplasm might be ascertained.

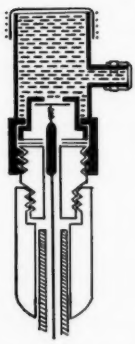

FIG. 1. Diagram of the crystal chamber which can be applied directly to the surface of the brain. Stretched over the upper end is a sheet of condom rubber; the filling medium is water.

The problem first centered itself around whether or not the texture of cerebral neoplasms varied sufficiently from normal tissue to be differentiated by this ultrasonic vibration method. The second problem was whether or not one could by this method establish with reasonable accuracy the presence of a subcortical neoplasm. The third problem was to ascertain whether or not pulsed ultrasonic vibrations of the proposed frequencies produced damage to cerebral tissues.

For these experiments a crystal from an ultrasonic Trainer device, 15-Z-1 developed by the Special Devices Center of the U. S. Navy, was mounted in a cylindrical chamber (ultrasonascope) as shown in Fig. 1. The crystal or transducer was caused to resonate electronically at a frequency of 15 megacycles per second, i.e., 15 million times per second. The sound waves generated by the transducer pass through the water contained in the chamber, through

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the rubber membrane stretched across the top, and on through any biological tissue placed in contact with the rubber membrane. The transducer vibrates for a duration of $\frac{1}{2}$ of a millionth of a second and is then stopped, so that pulses of ultrasonic energy are produced. The echoes resulting from reflection of the vibrations are received by the transducer during the quiescent periods. The echoes are continuously recorded on a synchroscope, and they can be photographed for the purpose of obtaining permanent records.

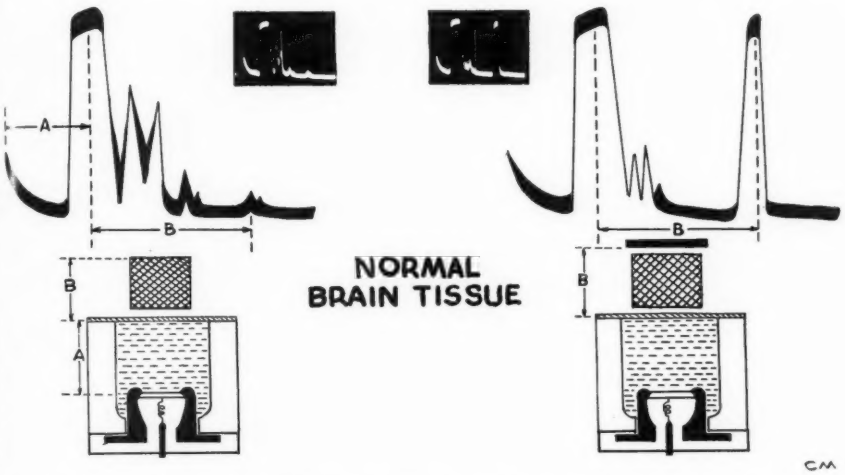


FIG. 2. Shows a composite explanatory arrangement referred to in the text of the experiments conducted with a piece of normal cerebrum.

In an attempt to answer the first problem, i.e., of comparative tissue textures, normal and neoplastic cerebral tissues were removed surgically and immediately examined. Neoplasms diagnosed histologically as being ependymoma, ependymoblastoma, glioblastoma, astrocytoma and metastatic were examined. In Fig. 2 are shown two photographs of the synchroscope tracings obtained when ultrasonic waves were sent through a piece of normal cerebrum measuring 1.43 cm. in thickness. The actual synchroscope tracings can be seen together with enlarged drawings. The distance designated "A" represents approximately the time interval for the pulse to reach the rubber membrane and to return. The distance "B" represents the time interval required for the pulse to pass through the tissue laid upon the rubber membrane and for the echo from the tissue-air interface to return to the rubber membrane. In order to check the position of the tissue-air interface, a piece of 26 gauge aluminum was placed on top in contact with the tissue. The strong return echo from this piece of metal can be observed in the tracings to the right.

Reference to the tracings in Fig. 3 shows a comparable experiment carried out with a piece of tumor tissue diagnosed as an ependymoblastoma (Fig. 4). It was found that the apparatus available would not penetrate tumor tissue of the same thickness as the normal cerebral tissue used in the

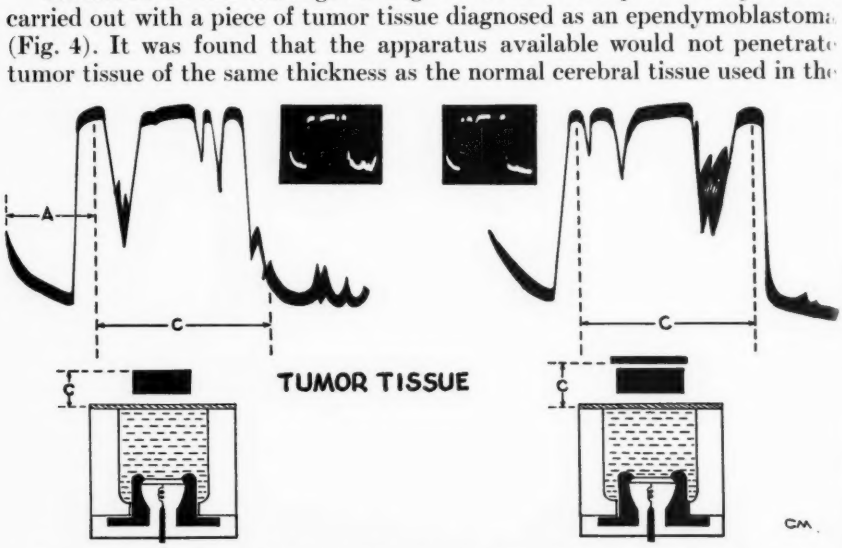


FIG. 3. Shows comparable experiments with a piece of ependymoblastoma approximately one-half as thick as the normal cerebral specimen. These experiments are also explained in the text.

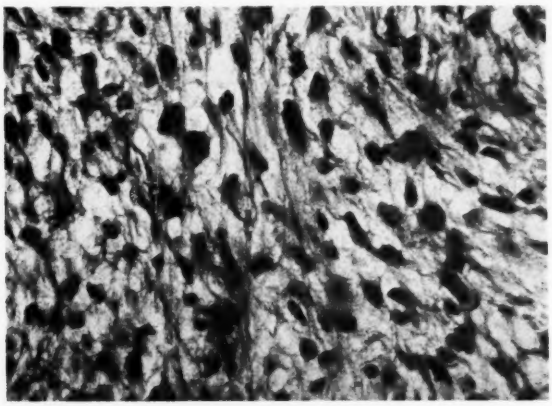

FIG. 4. Photomicrograph of ependymoblastoma from which the records in Fig. 3 were obtained.

experiment above. Accordingly, the tumor tissue was reduced to .64 cm. thickness, approximately one-half that of the normal brain tissue. The position of the tissue-air interface was verified as before with a piece of aluminum. The base-line interval "C" was found to be almost the same as for the normal tissue of twice the thickness. Therefore, the tumor tissue pro-

duced an ultrasonic response twice as great as the normal cerebral tissue from which it arose. Comparable results were obtained when the other glial and the metastatic tumors were examined. It was then felt that tumor tissue in situ could be detected and differentiated from the normal cerebral tissue.

For the second part of the experiment the whole brain was removed immediately after death from patients who clinically were believed to have died from brain tumors. The ultrasonascope was then applied to several

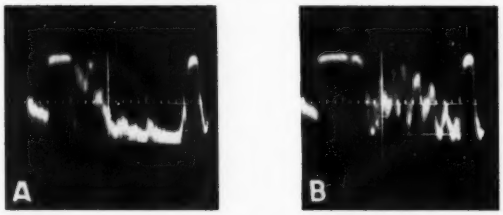


FIG. 5. Synchroscope recordings from (A) normal cerebral tissue, and (B) neoplastic tissue (glioblastoma multiforme).

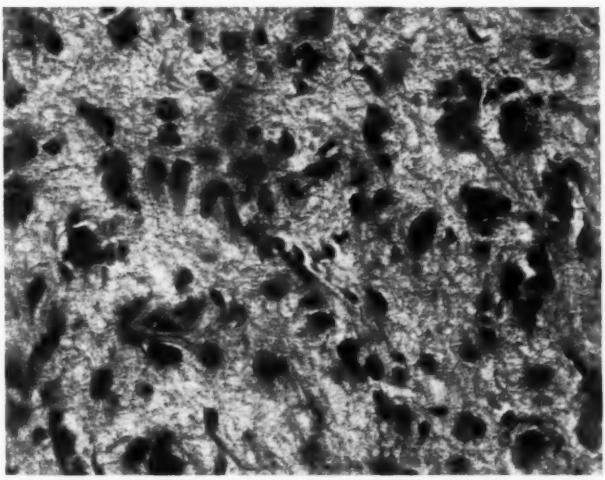

FIG. 6. Photomicrograph of glioblastoma multiforme from which records in Fig. 5 were obtained.

areas over the surface of the brains so that they were ultrasonically scanned. The amplitude and number of the return signals from these different areas were observed. Whenever the ultrasonagram suggested the possibility of an underlying neoplasm that area was scrutinized more carefully. In Fig. 5 are shown ultrasonagrams obtained (A) from cortex overlying normal brain and (B) from cortex overlying a neoplasm. The neoplasm was a glioblastoma (Fig. 6). In Fig. 7 are shown ultrasonagrams obtained from the cortex of a patient who expired from a metastatic tumor (Fig. 8). Similar studies were

carried out on brains containing ependymomas and astrocytomas. In all of them it was possible with this method to detect the subcortical neoplasms.

According to the available literature[1,2,3,4] on the effect of sound there is reason to believe that continuous exposure to vibrations of 8,000 to 20,000 cycles per second can produce tissue damage. Therefore, it was necessary to investigate whether pulsed (intermittent) vibrations of 15 million cycles

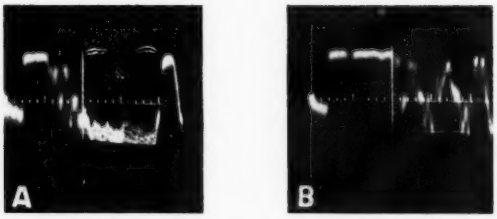


FIG. 7. Synchroscope recordings from (A) normal cerebral tissue one inch distant from a metastatic neoplasm, and (B) cerebral tissue overlying a metastatic neoplasm located 1 cm. subcortically. The greater amplitude and number of the return signals from the cortex overlying the neoplasm are apparent.

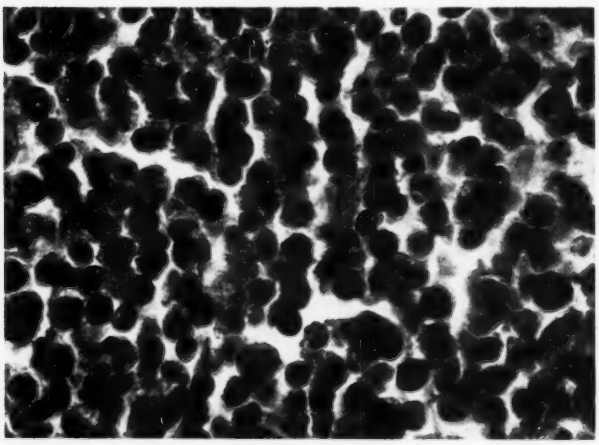

FIG. 8. Photomicrograph of metastatic tumor of brain located by means of the ultrasonic recordings in Fig. 7.

per second produced discernible damage to normal cerebral tissue. For this purpose the calvarium and dura overlying the cerebral hemisphere were removed surgically from 4 rabbits and 1 cat. Each cerebral hemisphere was then exposed to the pulsed ultrasonic vibrations for a period of 20 minutes. The dura and scalp were then sutured and the animals repeatedly examined for evidence of neurologic deficit. In none of the animals was clinical evidence of brain damage observed. The animals were sacrificed

at periods of 4 hours, 2 weeks, 4 weeks, 6 weeks and 8 weeks after exposure to the ultrasonic vibrations. Serial sections of the cerebral hemispheres were made and the sections stained with hematoxylin and eosin stain, Weil's stain, and Nissl's stain. The areas exposed to ultrasonic vibrations did not appear different than normal control areas of the same brain. No evidence of damage was found by such histological studies.

## SUMMARY

1. Pulsed ultrasonic vibrations have been sent through normal and neoplastic cerebral tissues.

2. The texture of the neoplastic cerebral tissues is such that the ultrasonic response is approximately twice that of normal cerebral tissue.

3. Subcortical cerebral neoplasms have been located in postmortem material by this method of investigation.

4. Pulsed ultrasonic vibrations of this frequency did not produce demonstrable damage in the cerebral hemispheres of experimental animals.

## REFERENCES

1. Dognon, A., Biancani, E., and Biancani, H. Ultra-sons et biologie. *Paris: Gauthier-Villars*, 1937, vii, 80 pp.
2. Schmitt, F. O., Olson, A. R., and Johnson, C. H. Effects of high frequency sound waves on protoplasm. *Proc. Soc. exp. Biol., N. Y.*, 1928, *25:* 718–720.
3. Williams, O. B., and Gaines, N. The bactericidal effects of high frequency sound waves. *J. infect. Dis.*, 1930, *47:* 485–489.
4. Wood, R. W., and Loomis, A. L. The physical and biological effects of high-frequency sound-waves of great intensity. *Phil. Mag.*, 1927, 7s. *4:* 417–436.

# TREATMENT OF OBSTRUCTIVE HYDROCEPHALUS BY PUNCTURE OF THE LAMINA TERMINALIS AND FLOOR OF THE THIRD VENTRICLE

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NUMEROUS procedures have been devised over the years to relieve obstructive hydrocephalus by diverting the cerebrospinal fluid from the obstructed ventricles into tissue spaces or systems unsuited to the natural disposal of this fluid, such as the subdural space, the subgaleal space, the peritoneal cavity, or the genito-urinary system.

The principle that it is necessary to drain the cerebrospinal fluid from the obstructed ventricles into the subarachnoid space, whence it can be removed by natural physiologic mechanisms, was first stated by Dandy. In 1922,[1] he described an operation for establishing communication between the third ventricle and the cisterna interpeduncularis. Dandy approached the chiasm through a small frontal flap, divided the optic nerve, elevated the optic chiasm and tract, and made a puncture into the hypothalamic portion of the third ventricle. He performed this operation on 6 patients but gave no case reports and made no claim for its success. He subsequently modified his technique to avoid dividing the optic nerve; this he did by approaching the hypothalamus through a temporal flap and along the floor of the middle fossa. There are no case reports of this operation by Dandy.

In 1936, Stookey and the present writer[3] reported a different method for third ventriculostomy, which they described as "puncture of the lamina terminalis and floor of the third ventricle." The technique of this operation is here given.

## TECHNIQUE

A coronal incision is made, following which a small right frontal osteoplastic flap is turned up. This is carried down as low onto the brow as the frontal sinus will permit, and directly to the midline. A dural flap is then reflected toward the midline. The lateral ventricle is tapped to relieve pressure, following which the frontal lobe is retracted from the floor of the frontal fossa to expose the optic chiasm and perichiasmal region (Fig. 1). The optic chiasm in hydrocephalus lies close to the tuberculum sellae. A thin arachnoid membrane stretches upward from the superior surface of the chiasm to the under surface of the frontal lobes. Immediately behind this membrane lies the cisterna chiasmatis, the posterior wall of which is the lamina terminalis. In typical cases of hydrocephalus, the lamina terminalis is seen as a bulging membrane about 1–1.5 cm. in diameter, which appears dark blue. The membrane is quite thin, and its apparent color is due to light reflected back from fluid within the distended third ventricle. A small incision is made through the arachnoid mem-

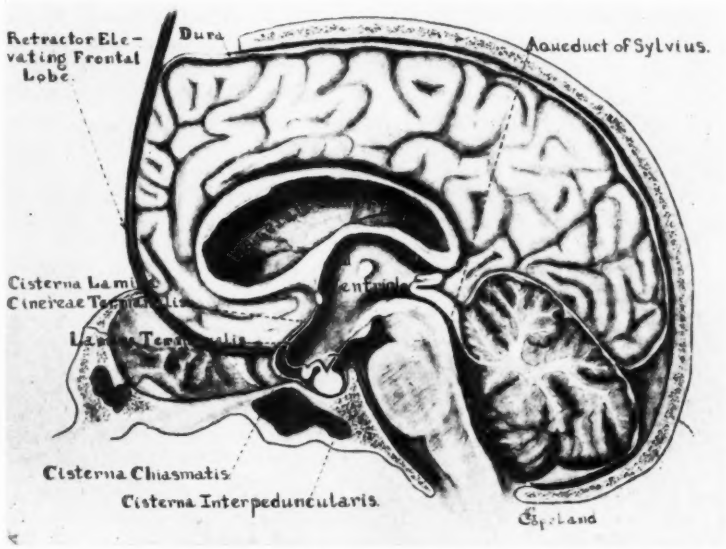


FIG. 1. Anatomical structures involved in puncture of lamina terminalis and floor of third ventricle The anterior wall of the cisterna chiasmatis is formed by an arachnoid membrane, while the posterior wall is the lamina terminalis itself. The attenuated floor of the third ventricle forms the anterior boundary of the cisterna interpeduncularis. The arrows indicate the points at which communication is established by the operation between the third ventricle and the two cisternae. (Drawing reproduced from original description of operation.[3])

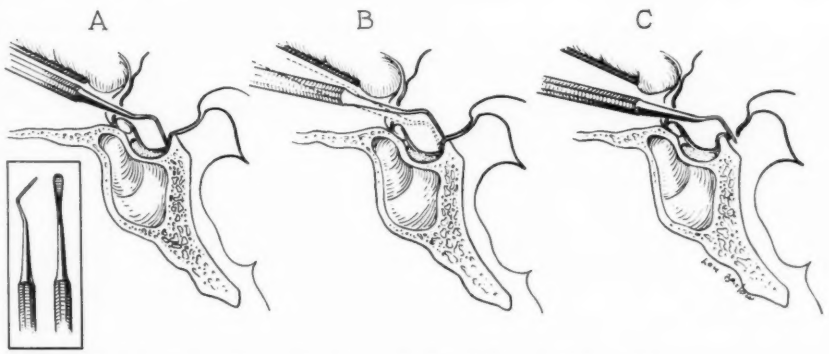


FIG. 2. Technique of puncture of lamina terminalis and floor of third ventricle.

(A) The anterior arachnoid walls of the cisterna chiasmatis and the lamina terminalis have been incised, and a dental instrument has been introduced through these incisions into the third ventricle until its tip is brought into contact with the dorsum sellae.

(B) The tip of the dental instrument, guided entirely by sense of touch, has been gradually made to "walk up" the inner wall of the dorsum sellae until the tip rests on the lip of the dorsum.

(C) The tip of the instrument has been advanced over the lip of the dorsum sellae, tearing a rent in the paper-thin floor of the third ventricle, and thus establishing communication between the ventricle and the interpeduncular cistern.

brane forming the anterior wall of the cistern, and a second and larger opening is made through the thinned-out, bulging lamina terminalis. As soon as this is done, the intraventricular fluid escapes with a gush.

A blunt tipped dental instrument, bent to an angle of about 45° at 1 cm. from its end (hockey stick shape), is then introduced through the openings in the arachnoid and lamina terminalis, and thence into the third ventricle (Fig. 2). The instrument is advanced parallel to the longitudinal axis of the skull and in a plane parallel to the floor of the frontal fossa, until its down-pointing end engages the dorsum sellae. Finding this important landmark is the key to the successful puncture of the floor of

FIG. 3. The attenuated floor of the third ventricle in a typical case of obstructive hydrocephalus. The hypothalamic nuclei normally present in this region have either been displaced laterally or destroyed by pressure. This explains the absence of hypothalamic symptoms following puncture of the floor of the third ventricle.

the third ventricle. The tip of the instrument is then gradually made to "walk up" the inner wall of the dorsum sellae by a succession of light tapping movements, until it reaches the crest of the dorsum near its midline. As soon as it passes the crest, resistance afforded by the bony dorsum is no longer felt. A very slight forward pressure will now result in the tip of the instrument perforating the floor of the third ventricle and dropping ventrally into the interpeduncular cistern. The angulated portion of the instrument should measure about 1 cm. If it is this length, its ventral progress will be arrested by the shaft of the instrument striking the dorsum sellae before its tip can damage important blood vessels, mid-brain, or brain stem. The tip is then gently moved 4–5 mm. in all directions to further enlarge the opening in the third ventricle. The floor is so thin (Fig. 3) that practically no resistance is encountered in doing this. This maneuver completes the puncture *per se*, and the instrument is then withdrawn.

Before closure of the dura, a ventricular needle is passed through the frontal cortex into the lateral ventricle, and the ventricle is re-distended with Ringer's solution. The dura, pericranium, galea, and scalp are then closed as nearly water-tight as possible with interrupted sutures. No drains are used. Occasionally cerebrospinal fluid may collect in the space between the frontal lobe and the dura within the first few postoperative days. Should this occur, the fluid should be removed by aspiration. The necessity for this is greatly reduced if care is taken to re-distend the ventricle with Ringer's solution, as above described, before the dura is closed.

Essential points in the technique are: (1) extension of the frontal flap as close to the floor of the frontal fossa, and as near to the midline, as possible; (2) advancement of the dental tool through the hypothalamic portion of the third ventricle in a true A-P direction (danger lies in advancing the tool diagonally because of the hazard of puncturing the cavernous sinus); (3) identification of the dorsum sellae by the tip of the instrument; (4) continued firm pressure of the tip of the advancing instrument on the dorsum sellae up to the moment of puncture.

This operation fulfills the principal theoretical requirements for a successful by-passing operation. (1) The intraventricular fluid from both lateral ventricles is drained directly into a large subarachnoid space, the cisterna interpeduncularis. (2) The floor of the third ventricle, through which the opening is made, is almost paper-thin, which minimizes chances of its closure. (3) The interpeduncular cistern is prevented from collapsing by the cerebral peduncle on each side of it. And (4) from the interpeduncular cistern, the fluid is immediately distributed out over the surface of the cerebral hemispheres, whence it is absorbed by natural mechanisms.

The hypothalamic nuclei are rarely disturbed if the technique described is rigidly observed. In the hydrocephalic patient, the floor of the third ventricle is already greatly distended and reduced to the thinness of tissue paper, and the hypothalamic structures are attenuated and atrophic. In the author's experience with this operation, there have been only 2 cases in which postoperatively there were clinically significant disturbances which could be attributed to damage of the hypothalamic nuclei. Both of these children died of hyperthermia within the first postoperative day. In no other case has there been any significant disturbance of heat regulation, vasomotor tone, respiratory rhythms, or water metabolism.

This operation has now been performed by Stookey and the present writer on 34 patients suffering with obstructive hydrocephalus. Of these, 16 had primary hydrocephalus due to stenosis of the aqueduct of Sylvius, and 18 had secondary hydrocephalus due to tumor. The results were considered good in primary hydrocephalus only if intracranial pressure was permanently relieved; and in hydrocephalus due to tumor, only if all symptoms and signs of intracranial pressure subsided immediately after operation and remained absent for 6 months or until death occurred from causes other than hydrocephalus. Using these criteria, the results in these 34 operations can be summarized as follows: 5 patients died in the hospital; 10 patients were discharged from the hospital without, however, permanent relief of intracranial pressure; and 19 patients survived the operation and realized permanent relief of pressure. These 19 represent 54 per cent of the entire series, a summary of which is given in Table 1.

Puncture of the floor of the third ventricle in addition to puncture of the lamina terminalis has been criticized by some as being unnecessary and adding appreciably to the operative risk. For this reason, a control series of 10 cases was carried out by the writer, in which puncture of the lamina

## TABLE 1

*Results obtained in the treatment of obstructive hydrocephalus by puncture of the lamina terminalis and floor of the third ventricle*

| Case | Sex | Age | Pathology | Postoperative Result |
|---|---|---|---|---|
| | | | *Original series* reported in 1936.[3] | |
| 1. | M | 40 yrs. | ? Tumor, posterior to 3rd vent. | *Good.* Pressure relieved. Still asymptomatic 3 yrs. postop. Relief of headache, unsteady gait, visual hallucinations & weakness both legs. |
| 2. | F | 14 yrs. | Aqueduct stenosis | *Good.* Pressure relieved. Still well 14 mos. postop. No complaints of visual or gait disturbances. Attending school. |
| 3. | M | 14 yrs. | Tumor, posterior to 3rd vent. | *Poor.* Pressure unrelieved. Died 1 mo. postop. after + gait disturbance, diplopia, failing vision, dizzy spells & polydipsia. |
| 4. | M | 11 yrs. | Aqueduct stenosis | *Good.* Pressure relieved. Postop. condition excellent; relief of headaches, vomiting, papilledema & stupor. Still asymptomatic, working daily, July '50. |
| 5. | M | 14 yrs. | Tumor of pons | *Good.* Pressure relieved. Still alive 7 mos. postop.; no papilledema, but focal symptoms of tumor +. |
| 6. | M | 14 yrs. | Glioblastoma 3rd vent. | *Died* 2 days postop. |
| | | | *Additional cases* 1937 through 1949. | |
| Case | Date of Op. | Age | Pathology | Postoperative Result |
| 7. | E.B. 520846<br>7-2-37<br>7-19-37 | 11 yrs. | Tumor, periaqueductal | *Good.* Pressure relieved. 9 yrs. later, still pressure free. |
| 8. | V.H. 34545<br>10-2-37<br>4-12-39 | 35 yrs. | Tumor, cerebellar | *Good.* Pressure relieved. 2 yrs. later, tumor grew. Exploration: extensive adhesions around foramina. Catheterization of aqueduct attempted; pt. died. |
| 9. | E.R. 583692<br>10-28-37 | 24 yrs. | Aqueduct stenosis | *Good.* 4 yrs. postop., condition still excellent; no signs of + pressure. |
| 10. | R.D. 35450<br>11-2-37<br>12-3-37 | 4 mos. | Leptomeningitis | *Poor.* Pressure recurred in 3 wks. Reop. for exploration; died 1st postop. day. Autopsy: Hemorrhages at op. site; opening through lamina term. & floor 3rd vent. still patent; ++ dilated ventric. system; other basal cisterns obliterated by aseptic adhesive arachnoiditis. |
| 11. | R.H. 36089<br>12-17-37 | 2 mos. | Aqueduct stenosis | *Poor.* Pressure relieved, but recurred 1 wk. after pt. discharged. Died 6 mos. postop. |
| 12. | J.J. 525514<br>1-5-38 | 6 mos. | Spongioblastoma polare, 3rd vent. | *Poor.* Died 6 wks. postop. |

TABLE 1—*continued*

| Case | Date of Op. | Age | Pathology | Postoperative Result |
|---|---|---|---|---|
| 13. | F.C. 39566<br>10-11-38 | 4 mos. | Aqueduct stenosis | *Poor.* Pressure relieved, but recurred 1 mo. postop. Ventriculography 2 mos. later; died 4 days postop. of ++ pressure. |
| 14. | G.C. 560984<br>10-21-38 | 10 mos. | Aqueduct stenosis | *Died* 1st postop. day. Hyperthermia. |
| 15. | L.M. 39770<br>11-8-38<br>12-6-38 | 11 yrs. | Aqueduct stenosis; ependymitis | *Poor.* Pressure unrelieved. Died 30 days postop. |
| 16. | A.T. 42482<br>8-17-39 | 31 yrs. | ? Aneurysm, basilar artery | *Died* during op. following ++ uncontrollable arterial hemorrhage from interpeduncular cistern. No autopsy. |
| 17. | G.H. 44025<br>1-15-40 | 14 yrs. | Tumor, cerebellar | *Good.* Pressure relieved. 3 mos. postop., pressure still normal, but tumor grew. Died of tumor 6 mos. postop., in chronic care hosp. |
| 18. | E.L. 652333<br>10-7-41<br>11-6-41 | 11 yrs. | Aqueduct stenosis | *Poor.* 1st op.: lamina term. puncture only. 2nd op.: lamina term. opening patent; floor of 3rd vent. punctured. Discharged to chronic care hosp. when pressure persisted. |
| 19. | L.B. 630951<br>10-22-41 | 23 yrs. | Chronic arachnoiditis of post. fossa | *Poor.* Pressure relieved. Discharged 31 days postop. But pressure recurred & steadily +. Died 5 mos. postop. ? pre- & postop. of inflammatory closure of subarachnoid cisterns, since pt. had had 8th nerve tumor. |
| 20. | P.M. 727617<br>11-24-43 | 25 yrs. | Aqueduct stenosis | *Good.* Pressure relieved. Discharged 18 days postop. 5 yrs. later, condition still excellent. |
| 21. | C.L. 816164<br>2-15-46 | 29 yrs. | Aqueduct stenosis | *Good.* Uneventful recovery. Discharged 20 days postop. No impairment of vision, papilledema, optic atrophy, diplopia 8 mos. postop. |
| 22. | R.W. 857132<br>2-3-47 | 53 yrs. | Tumor periaqueductal | *Good.* Pressure relieved. Pt. lived 2 yrs. after op. |
| 23. | S.Z. 866571<br>4-25-47 | 11 wks. | Aqueduct stenosis | *Good.* Pressure relieved. Excellent condition 3 yrs. after op. |
| 24. | M.J. 859761<br>6-25-47 | 1 yr. | Aqueduct stenosis | *Good.* Stormy postop. course, but outcome good. 2½ yrs. postop., physically well but rated mentally as "idiot." |
| 25. | B.P. 862973<br>7-3-47 | 4 yrs. | Obstruction below 3rd vent. ? Aqueduct stenosis | *Died* 2nd postop. day. Convulsions & hyperthermia. |

TABLE 1—*continued*

| Case | Date of Op. | Age | Pathology | Postoperative Result |
|---|---|---|---|---|
| 26. | R.G. 887343 10-29-47 | 12 yrs. | Pinealoma | *Good.* Pressure relieved. 2 yrs. postop. tumor filled cisternal spaces; pt. died. |
| 27. | S.M. 899514 3-22-48 | 17 mos. | Aqueduct stenosis | *Good.* Pressure relieved. 2 yrs. postop., condition still excellent. |
| 28. | M.W. 904090 4-14-48 | 52 yrs. | Pinealoma | *Good.* Pulse & respirations slowed during puncture floor 3rd vent. Excellent recovery; relief of pressure. 20 mos. postop., no signs of + pressure. |
| 29. | G.G. 893950 6-25-48 | 1 yr. | No obstruction found at autopsy | *Died* 2nd postop. day. Immediately postop., reactive, taking feedings well, moving all extremities, temp. 105°, pulse 240, resp. not countable. Autopsy (limited to head): no structural explanation for death. |
| 30. | M.B. 915632 7-12-48 | 47 yrs. | Pinealoma | *Good.* Tolerated op. well. Preop. stupor disappeared; talking, eating well, up in chair. On 8th postop. day, sudden cardiac failure. ? pulmonary embolus. No autopsy. |
| 31. | M.R. 909047 10-18-48 | 3 mos. | Aqueduct stenosis | *Good.* Poor prognosis given, but mother wrote 14 mos. postop.: pt. alive & well. |
| 32. | J.C. 897330 11-28-48 | 6 mos. | Cyst, cerebellar | *Poor.* Died 5 wks. postop. Autopsy: Unsuspected cerebellar cyst with ++ compression brain stem. |
| 33. | D.O. 762141 10-27-49 | 6 yrs. | Obstruction at exit of 4th vent.; ? Arnold-Chiari | *Poor.* Pressure relieved. Then sudden death 1 mo. postop., after 2 days' illness with severe pains in back of neck. No autopsy. |
| 34. | W.Z. 962030 12-7-49 | 5 mos. | Aqueduct stenosis | *Good.* Pressure relieved. Pt. alive & well 6 wks. postop. |

*Tabulation of Table 1*

| | No. of Cases | Hospital Deaths | Poor Results | Good Results |
|---|---|---|---|---|
| Total series | 34 | 5 (15%) | 10 (29%) | 19 (56%) |
| Aqueduct stenosis | 16 | 2 (13%) | 4 (25%) | 10 (62%)* |
| Tumors | 13 | 1 ( 8%) | 3 (23%) | 9 (69%) |
| Miscellaneous | 5 | 2 (40%) | 3 (60%) | — |

* Patients all living and well at present time; survival periods: 6 wks., 8 mos., 14 mos., 14 mos., 2 yrs., 2½ yrs., 3 yrs., 4 yrs., 5 yrs., 15 yrs.

## TABLE 2

*Control Series*

*Treatment of obstructive hydrocephalus by puncture of the lamina terminalis alone*

| Case | Date of Op. | Age | Pathology | Postoperative Result |
|---|---|---|---|---|
| 1. | V.S. 602935<br>3-12-40<br>4-18-40<br>5-7-40 | 29 days | Aqueduct stenosis | *Poor.* Despite 3 ops., pressure recurred 3 wks. after discharge. Died 40 days postop. |
| 2. | J.T. 609143<br>8-12-40 | 6 mos. | Aqueduct stenosis | *Poor.* Pressure recurred 3 wks. postop. Died 2 mos. after op. Autopsy: Occlusion of F. Magendie & Luschka. |
| 3. | V.M. 614485<br>8-8-40 | 7 mos. | Subependymal tissue split over both frontal horns | *Died* 24 hrs. postop. Autopsy revealed no cause for death; open 3rd vent., aqued. Sylvius, 4th vent. & F. Magendie & Luschka. (? Error in diagnosis type hydroceph.) |
| 4. | M.T. 614454<br>9-14-41 | 25 yrs. | Schwannoma, left | *Poor.* Pressure unrelieved. Downhill course. Died 3 mos. postop. in chronic care home. |
| 5. | P.M. 647506<br>7-5-41 | 4 mos. | Aqueduct stenosis. | *Good.* Pressure relieved. Still well 5 yrs. postop.; intelligence apparently normal. |
| 6. | J.S. 647527<br>7-10-41 | 5 mos. | Aqueduct stenosis | *Good.* Fontanelle still bulging 3 mos. postop. But mother wrote Feb. '50: child lived for 5 yrs., walked, talked, appeared "very bright." Died of unspecified cause. |
| 7. | C.G. 661880<br>12-31-41 | 8½ yrs. | Piloid astrocytoma, quadrigeminal plate | *Poor.* Pressure unrelieved. Then had Torkildsen op. Purulent meningitis developed. Autopsy: Acute & chronic leptomeningitis. No perceptible puncture in lamina term. |
| 8. | B.S. 661849<br>1-3-42 | 9 yrs. | Aqueduct stenosis | *Good.* Pressure relieved. Health still excellent 3½ yrs. postop. |
| 9. | H.H. 787522<br>5-29-45 | 29 yrs. | Aqueduct stenosis | *Good.* Pressure, tremor & headache relieved; vision improved. No long-term follow-up. |
| 10. | R.G. 892215<br>12-5-47 | 15 yrs. | Aqueduct stenosis | *Good.* 1 yr. postop., physician reported pt. in good condition, doing well. |

*Tabulation of Table 2*

| | No. of Cases | Hospital Deaths | Poor Results | Good Results |
|---|---|---|---|---|
| Total series | 10 | 1 (10%) | 4 (40%) | 5 (50%) |
| Aqueduct stenosis | 7 | — | 2 (28%) | 5 (72%) |
| Tumors | 2 | — | 2 (100%) | — |
| Miscellaneous | 1 | 1 (100%) | — | — |

terminalis alone was performed. The results in this series were as follows number of cases—10; hospital deaths—1; poor results—4; good results—5. It would appear that the double puncture increases the operative risk by 5 per cent, but at the same time increases the percentage of good results by 15 per cent. A summary of the control series is given in Table 2.

Consideration was given to the relative operative risks and results obtained by third ventriculostomy and by the Torkildsen operation, which employs permanent tube drainage of the obstructed cerebrospinal fluid from the lateral ventricle into the cisterna magna. Since Torkildsen[4] first described this method, it has been employed at the Neurological Institute of New York by staff members other than the writer in 20 cases. The results obtained in this series are as follows: number of cases—20; hospital deaths—3 (15 per cent); operative survivals without permanent relief of intracranial pressure—8 (40 per cent); survivals with permanent relief of pressure—9 (45 per cent). It would appear that the operative hazards for the Torkildsen operation and for third ventriculostomy are essentially the same and that the results on a whole are comparable.

## DISCUSSION

A great advantage of the puncture of the lamina terminalis and floor of the third ventricle is that it by-passes obstructions occurring at all points in the ventricular system and the basal cisterns, up to though not including the cisternae interpeduncularis and chiasmatis. In particular, it by-passes all obstructions occurring at the incisura whether due to neoplastic enlargements of the brain stem or to post-inflammatory occlusions of the pia arachnoid. Such incisural obstructions are not effectively dealt with by any other by-passing procedure.

The principal limitation of this operation is that it cannot be used where the hypothalamic portion of the third ventricle has been filled by tumor; under these circumstances, the Torkildsen[4] or Hyndman procedure[2] must be used. Nor can puncture of the lamina terminalis and floor of the third ventricle be used in cases where the interpeduncular or chiasmatic cistern is obliterated by cicatricial or neoplastic closure; under these circumstances, no by-passing operation is effective.

A commonly cited objection to the Stookey-Scarff third ventriculostomy is that it allows for no exploration of the posterior fossa. This is of relatively little importance in infants, because of the low incidence of cerebellar tumors in this age group. In older children and adults, where cerebellar tumors are more common, this procedure should not be employed unless such a tumor has been excluded securely on clinical grounds or by ventriculography.

## SUMMARY

(1) The results obtained in the treatment of obstructive hydrocephalus, both primary and secondary, by puncture of the lamina terminalis and floor of the third ventricle are reported in a series of 34 operations performed

by the originators of the procedure, Stookey and Scarff. Five patients died in the hospital; 10 experienced only temporary relief of intracranial pressure; and 19 realized permanent relief of pressure.

(2) The results obtained by puncture of the lamina terminalis and floor of the third ventricle were compared with results obtained by puncture of the lamina terminalis alone. It was found that with the single puncture, the operative mortality was 5 per cent lower, but that there were 15 per cent fewer permanent cures.

(3) The results obtained by puncture of the lamina terminalis and floor of the third ventricle were compared with results obtained by the use of the Torkildsen procedure at the Neurological Institute of New York. The operative mortality was essentially the same in the two series and the percentage of good results obtained was comparable.

## REFERENCES

1. Dandy, W. E. An operative procedure for hydrocephalus. *Johns Hopk. Hosp. Bull.*, 1922, *33:* 189.
2. Hyndman, O. R. Hydrocephalus. A contribution related to treatment. *J. Neurosurg.*, 1946, *3:* 426–443.
3. Stookey, B., and Scarff, J. Occlusion of the aqueduct of Sylvius by neoplastic and non-neoplastic processes with a rational surgical treatment for relief of the resultant obstructive hydrocephalus. *Bull. neurol. Inst., N.Y.*, 1936, *5:* 348–377.
4. Torkildsen, A. A new palliative operation in cases of inoperable occlusion of the Sylvian aqueduct. *Acta chir. scand.*, 1939, *82:* 117–124.

# CASE REPORTS AND TECHNICAL NOTES

## EPENDYMOBLASTOMA GROSSLY ERODING AND INVOLVING OVERLYING DURA AND SKULL

### REPORT OF A CASE

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According to some writers,[4,8,9,13,15,23] ependymomas are benign circumscribed growths; to others[3,12,20,21] infiltrative but generally slowly growing. Only few ependymomas have a rapid course and fewer still are those that infiltrate the pia and seed in the spinal cord.[11,16,19,22] Moreover, although gliomas of the brain rarely, if ever, erode through the overlying dura or skull, we could find not a single instance in which an ependymoma involved and eroded through the adjacent dura and overlying skull[1,6,7,17] as may occur with certain meningiomas.[5]

The case herein presented represents an example of a highly malignant ependymo-

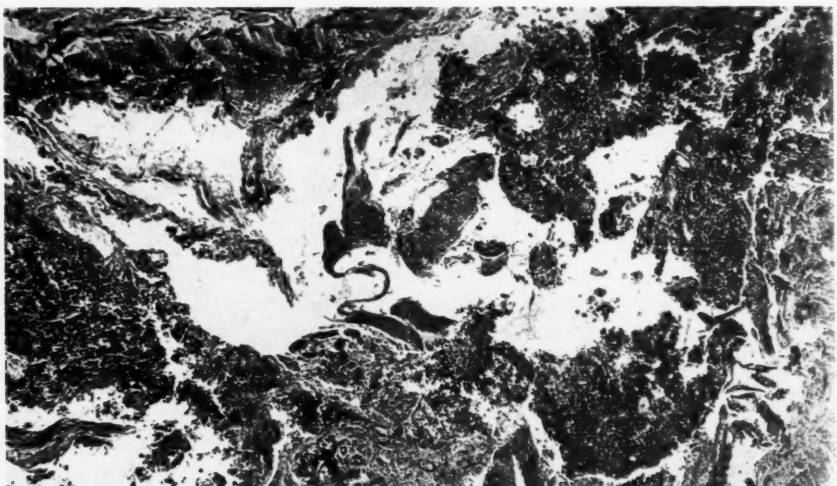

Fig. 1. Malignant ependymoblastoma infiltrating through the meninges. Hematoxylin and eosin stain, ×35.

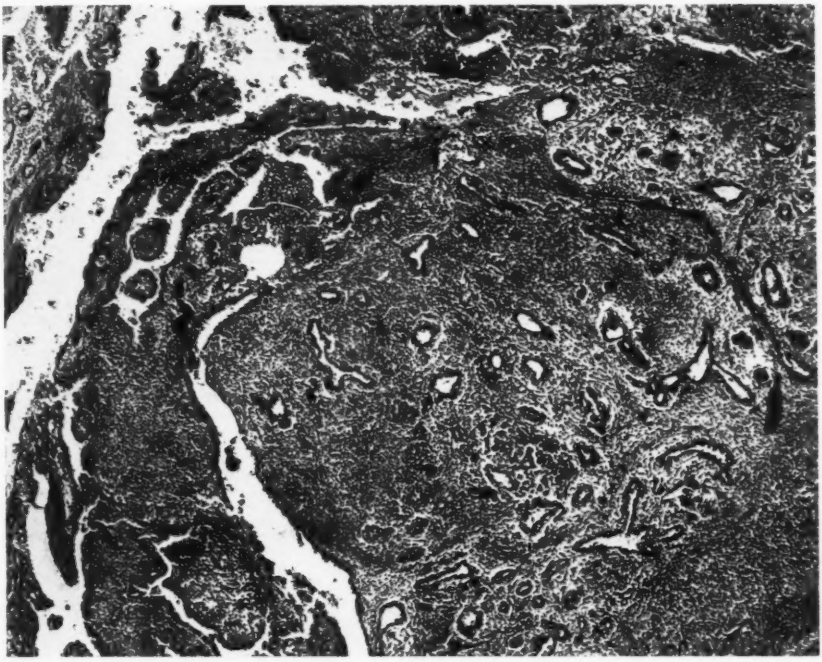

FIG. 2. The canals are interlaced with the cellular sheets. Hematoxylin and eosin stain, ×35.

blastoma arising in the right frontal lobe which grossly invaded and traversed the overlying dura and likewise grossly invaded the supra-adjacent skull. Such behavior on the part of a glioma is unique in our experience and, to our knowledge, in the literature and hence is considered worthy of a report.

## CASE REPORT

Medical College of Virginia No. 62239. Mrs. E.S., a white housewife aged 21 years, was first admitted on May 23, 1949 complaining of headache, vomiting and diminution of vision. One month previously, following termination of a normal pregnancy, nausea, vomiting and daily headache with amblyopia developed.

*Examination.* The pupils were widely dilated and contracted only slightly to light. There was marked papilledema bilaterally. No focal neurologic signs were elicited and a presumptive diagnosis of increased intracranial pressure only could be made, without clinical localization.

*1st Operation.* A ventriculogram on May 23, 1949 disclosed the mass lesion to be unmistakably in the right frontoparietal region. Craniotomy was immediately undertaken. An extract of the operative note reads as follows: "After the right frontal scalp flap had been turned down, it was apparent that tumor tissue was protruding through multiple erosions in the bone through which was extending necrotic tumor tissue. After the bone flap had been reflected, the inner surface was found to contain tumor tissue in the area above the supra-orbital ridge. The exposed dura was very tense with neoplastic tissue which had grown through its exposed anterior portion. Tumor tissue had extended through the dura in an area

of 3 by 3 cm. However, a considerably greater circumference of the inner surface of the dura was involved. A frozen section diagnosis was reported as a rapidly growing, highly malignant tumor, probably gliomatous in nature. The dura was opened widely, revealing a very extensive, purplish-red, widely infiltrating growth, completely replacing the frontal lobe. It involved the entire prefrontal area and extended medially to the falx as well. No evidence of a capsule nor line of demarcation was apparent. The tumor was extremely soft, friable, necrotic, and variegated in appearance. There was considerable old hemorrhage present, and also fresh blood clot. At one point, a moderate-sized cyst containing perhaps 20 to 30 cc. of thin,

FIG. 3. Showing the structure of the ependymal cells lining the intercommunicating canals and the sheets of undifferentiated cells, i.e., a combination of epithelial and cellular ependymoma. Hematoxylin and eosin stain, ×120.

yellowish fluid was encountered. The growth was quite diffusely vascular save for the portions of greatest necrosis. After the bulk of the tumor and the involved dura had been removed, a piece of Polythene film was laid over the tumor cavity and the dural defect and the bone flap replaced as a free autograft and secured with two silver wires. The patient withstood the entire procedure satisfactorily with the aid of a blood transfusion."

*Postoperative Course.* The patient did well. There was early complete recession of the choked discs and after x-ray therapy (2000 R delivered to the tumor itself—June 1949) the tight decompression anterior to the bone flap receded to a concave status. She was symptom-free on discharge June 23, 1949, and resumed her usual duties as a housewife.

*Readmission.* However, not unexpectedly (because of the highly malignant nature of the tumor histologically), the patient was readmitted on Oct. 8, 1949. She had been doing well until 24 hours previously, when she began having severe headache, associated with nausea and vomiting. Vision had improved greatly since the operation 4½ months previously. The

area of frontal decompression (6×9 cm.) was extremely tense and elevated from the surrounding skull. This area was moderately tender to palpation and about the consistency of brain or firm tumor tissue.

*2nd Operation.* On Oct. 12, 1949 the previously placed scalp flap in the right frontal region was reflected. The bone flap was found to be firmly in place, being held by the 2 wire sutures. As the anterior edge of the bone flap was reached, a large tumor mass was encountered which grossly invaded the overlying scalp. A considerable mass of tumor was removed with the suction and biopsy rongeurs, estimated to be easily as large as one's fist. On completion

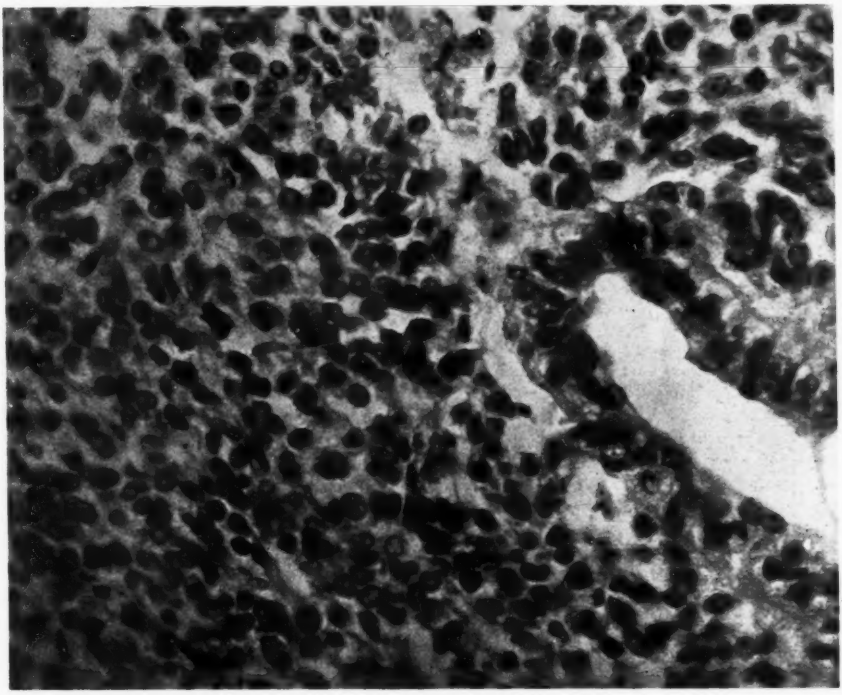

FIG. 4. Mitotic figures are present in the epithelium of the canals and in the cellular areas. Scattered among the diffuse cells are some vacuolated cells: oligodendroglial. Phosphotungstic acid hematoxylin stain, ×460.

of the operation, a marked concavity existed in place of the large protuberant mass before operation. The patient tolerated the operation satisfactorily, receiving a pint of blood on the table.

*Pathological Study.* Sections show the tumor tissue to be composed of two types of structures: (a) Blind and intercommunicating canals surrounded by loose stroma[18] (Fig. 3) and (b) canals surrounded by dense sheets of polyhedral and spindle cells (Figs. 2 and 4).

The cells lining the canals[21] range from low cuboidal to high columnar (Figs. 3 and 4). Some of the latter are ciliated (Fig. 3).

The cellular sheets are made up of cells that have ill-defined outlines among which can be identified certain cells each of which has a short process extending from one of the poles of the oval nucleus (Figs. 4 and 5). However, the general impression is that of a syncytial mass.[10,11] The nuclei of both the epithelial cells and the cellular sheets are very similar and uniform (Fig. 4.) Each has a delicate well-formed nuclear membrane, granular powdery chromatin

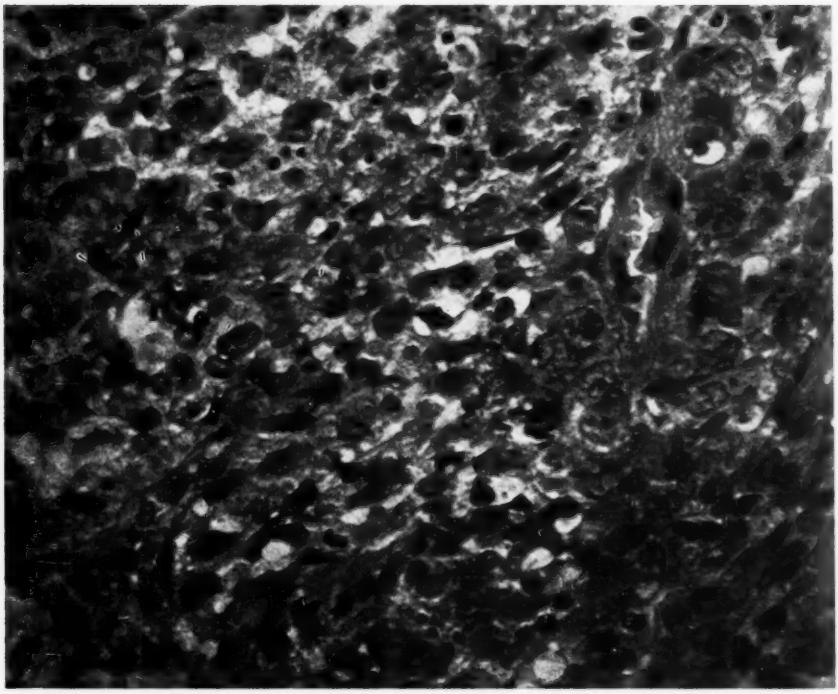

FIG. 5. The diffuse cells with mitotic figures are seen. The cells vary from polyhedral to spindle shape with ill-defined boundaries. The nuclei are rounded or oval with prominent nucleoli. The tendency towards spindle cells and the ill-defined outlines, a syncytial pattern, suggest a similarity to the syncytium of the mantle stage of the medullary epithelium. Phosphotungstic acid hematoxylin stain, ×460.

and multiple small nucleoli. Mitotic figures are found in both the epithelial and cellular elements of the tumor.[20] Neuroglia fibrils are consistently absent throughout the sections.

Although the tumor is moderately vascular, pseudo-rosettes are very few and rosettes were not found although numerous sections from different parts of the tumor were searched.

In certain fields, vacuolated cells with central nuclei having an oligodendroglial appearance are observed (Figs. 4 and 5).[2,14] In other fields sheets of vacuolated macrophages which were shown, by fat stain, to contain fat droplets are found. The latter made us take into consideration the possibility of a lipomatous meningioma as these sheets are most numerous in that part of the tumor that invaded the meninges.

Throughout the tumor extensive areas of necrosis are found (Fig. 1).

*Microscopic Diagnosis:* Ependymoblastoma (highly malignant).

*Postoperative Course.* This was fairly satisfactory. Several aspirations of the scalp flap to remove moderately sanguinous CSF were necessary to ensure proper healing of the wound. In October to November 1949, she received again 2000 R of x-ray therapy (tumor dose).

She was discharged Nov. 4, 1949 with a poor prognosis in view of the above histological diagnosis of the tumor. On Dec. 15, 1949 her husband wrote that she had died several days previously.

SUMMARY

A case of a highly malignant ependymoblastoma of the right frontal lobe in a 21-year-old woman is presented primarily to demonstrate the ability of such a gliomatous tumor grossly to invade and erode the overlying dura and skull—a rare occurrence in the gliomata.

REFERENCES

1. Bailey, P. Intracranial tumors. *Springfield, Ill.: Charles C Thomas*, 1948, 2nd ed., xxiv, 478 pp. (see pp. 156–184; 205–222).
2. Benedek, L., and Juba, A. Über die ependymalen Mittledorfschen Tumoren. *Arch. Psychiat. Nervenkr.*, 1942, *115:* 174–179.
3. Biryukov, M. L. [Morphologic signs of malignancy of ependymoblastoma.] *Vopr. Neyrokhir.*, 1941, *5:* 73–89.
4. Cairns, H., and Riddock, G. Observations on the treatment of ependymal gliomas of the spinal cord. *Brain*, 1931, *54:* 117–146.
5. Cushing, H., and Eisenhardt, L. Meningiomas. Their classification, regional behaviour, life history, and surgical end results. *Springfield, Ill.: Charles C Thomas*, 1938, xiv, 785 pp. (see pp. 21–22).
6. Dandy, W. E. The brain. In: *Lewis' practice of surgery.* Hagerstown, Md.: W. F. Prior Co., Inc., 1945, *12:* 671+17 pp. (see pp. 485–492).
7. Fincher, E. F., Jr. Intrinsic tumors of cerebrum. In: *Surgical treatment of the nervous system.* F. W. Bancroft and C. Pilcher, Ed. Philadelphia: J. B. Lippincott Co., 1946, 534 pp. (see pp. 154–175).
8. Fincher, E. F., Jr., and Coon, G. P. Ependymomas. A clinical and pathologic study of eight cases. *Arch. Neurol. Psychiat., Chicago*, 1929, *22:* 19–44.
9. Giampalmo, A. Zur Frage der extraventrikulären Ependymome. *Zbl. Neurochir.*, 1937, *2:* 283–290.
10. Globus, J. H., and Kuhlenbeck, H. Tumors of the striatothalamic and related regions. Their probable source of origin and more common forms. *Arch. Path.*, 1942, *34:* 674–734.
11. Globus, J. H., and Kuhlenbeck, H. The subependymal cell plate (matrix) and its relationship to brain tumors of the ependymal type. *J. Neuropath. exp. Neurol.*, 1944, *3:* 1–35.
12. Hirsch, E. F., and Elliott, A. R. Ependymomas of the lateral and fourth ventricles of the brain. *Amer. J. Path.*, 1925, *1:* 627–634.
13. Horrax, G., and Henderson, D. G. Encapsulated intramedullary tumor involving the whole spinal cord from medulla to conus: complete enucleation with recovery. *Surg. Gynec. Obstet.*, 1939, *68:* 814–819.
14. Kernohan, J. W., and Fletcher-Kernohan, E. M. Ependymomas. A study of 109 cases. *Res. Publ. Ass. nerv. ment. Dis.*, 1937, *16:* 182–209.
15. Kunicki, A. [Embryogenetic classification of ependymal tumors with two anatomicoclinical observations.] *Neurol. polska*, 1938, *21:* 84–112. Abst. in: *Zbl. Neurol. Psychiat.*, 1939, *92:* 560.
16. Mandeville, F. B., Russell, D. A., and Farley, M. S. Roentgen therapy of 100 consecutive tumors of the brain or spinal cord. *Radiology*, 1941, *37:* 560–568.
17. Pilcher, C. Tumors of meninges. In: *Surgical treatment of the nervous system.* F. W. Bancroft and C. Pilcher, Ed. Philadelphia: J. B. Lippincott Co., 1946, 534 pp. (see pp. 119–131).
18. Ringertz, N., and Reymond, A. Ependymomas and choroid plexus papillomas. *J. Neuropath. exp. Neurol.*, 1949, *8:* 355–380.
19. Spiller, W. G. Gliomatosis of the pia and metastasis of glioma. *J. nerv. ment. Dis.*, 1907, *34:* 297–302.
20. Svien, H. J., Camp, J. D., and Adson, A. W. Multiple primary tumors of the spinal cord. Report of case. *Surg. Clin. N. Amer.*, Aug. 1949, *29:* 1223–1231.
21. Swan, C. A clinico-pathological study of five cases of ependymoma. *Med. J. Aust.*, 1945, *1:* 561–566.
22. Tarlov, I. M., and Davidoff, L. M. Subarachnoid and ventricular implants in ependymal and other gliomas. *J. Neuropath. exp. Neurol.*, 1946, *5:* 213–224.
23. Tönnis, W., and Zülch, K. J. Das Ependymom der Grosshirnhemisphären im Jugendalter. *Zbl. Neurochir.*, 1937, *2:* 141–164.

# SPINAL TUMORS DIAGNOSED DURING THE FIRST YEAR OF LIFE

## WITH REPORT OF A CASE*

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In reviewing over 70,000 case histories from the Harriett Lane Home, Ford[13] was able to find only 3 cases of spinal cord tumor, the youngest of these 3 patients being 9 years of age. The literature bears out the rarity of intraspinal tumors in children.[14] Even more striking is the infrequency with which spinal tumors are diagnosed during the first year of life. In a review of 279 cases of spinal cord tumor collected by Antoni[3] and in a more recent review of 451 cases collected by Adson[1] no patient was found under 1 year of age. The author was able to find only 23 recorded instances in which an intraspinal tumor had been diagnosed during the first year of life. The purpose of this paper is to briefly review these 23 cases and to report an additional example of this unusual occurrence.

### CASE REPORT

P. R., male, aged 5 months, was admitted to the University Hospital on April 11, 1949. He had been born at term and weighed 8 lbs. at birth. The mother's pregnancy, labor, delivery, and postnatal course had been uneventful, and the patient was her 13th child. He had had several upper respiratory infections, the most recent being 2 weeks prior to admission. He cried with each bowel movement as though he were straining to defecate. The stools were hard and dry. During the last 2 weeks there was constant dribbling of urine with no urinary stream. Two weeks prior to admission the mother accidentally struck the patient's back. Within 24 hours weakness in the lower extremities was noted. This weakness progressed until at time of admission he was completely paralyzed in his lower extremities except for slight motion in the toes.

*Examination.* B. P. 96/62; pulse 110; respirations 24; rectal temperature 98.0°; weight 15 lbs. 14 oz. Pain and temperature perception were diminished below the level of the 1st lumbar dermatome. There was flaccid paralysis of both lower extremities with some motion retained in the toes. The deep tendon reflexes, normal in the upper extremities, were hypoactive in the lower extremities, with sustained ankle clonus on the left and unsustained ankle clonus on the right. Hb. 85 per cent. WBC 9600: 29 per cent polymorphonuclears; 68 per cent lymphocytes (24 per cent atypical); 2 per cent eosinophiles; 1 per cent monocytes. Reticulocytes 0.4 per cent; platelets 37,800. Urea nitrogen, blood sugar, heterophile antibody, and serological tests for syphilis were within normal limits.

Roentgenograms of the chest and abdomen showed no abnormality. Intravenous pyelography was negative. Roentgenograms of the spine showed minimal dilatation of the spinal canal at the level of the 12th thoracic and 1st lumbar vertebrae (Fig. 1).

Lumbar puncture disclosed a complete subarachnoid block with yellow fluid containing 1 lymphocyte and 4 +globulin. The fluid clotted on standing. Due to the unreliability of the sensory level a pantopaque myelogram was done and revealed a complete block, the lower end of which was between the 1st and 2nd lumbar vertebrae. Following myelography the patient became completely paraplegic.

*Operation.* April 19, 1949. Anesthetic: intratracheal ether and oxygen. The spines and laminae of the 12th thoracic and 1st lumbar vertebrae were removed, disclosing an extradural, reddish-brown, granulomatous tumor. The inferior edge of the growth lay within the operative field but it was necessary to remove the spine and laminae of the 11th thoracic vertebra in

* Aided by a grant from the Hoffberger Neurosurgical Fund.

order to expose the superior extent of the lesion. It was found that the tumor was of low vascularity, friable, and encircled the dural sac, but lay predominantly dorsally and on the left side. The tumor was removed piecemeal with curette. The muscles, fascia and skin were closed with silk.

*Subsequent Course.* The patient made an excellent recovery; 36 hours after operation he was again able to move his toes, and by the 10th postoperative day there was return of motor power to all muscle groups of both lower extremities with return of pain and thermal percep-

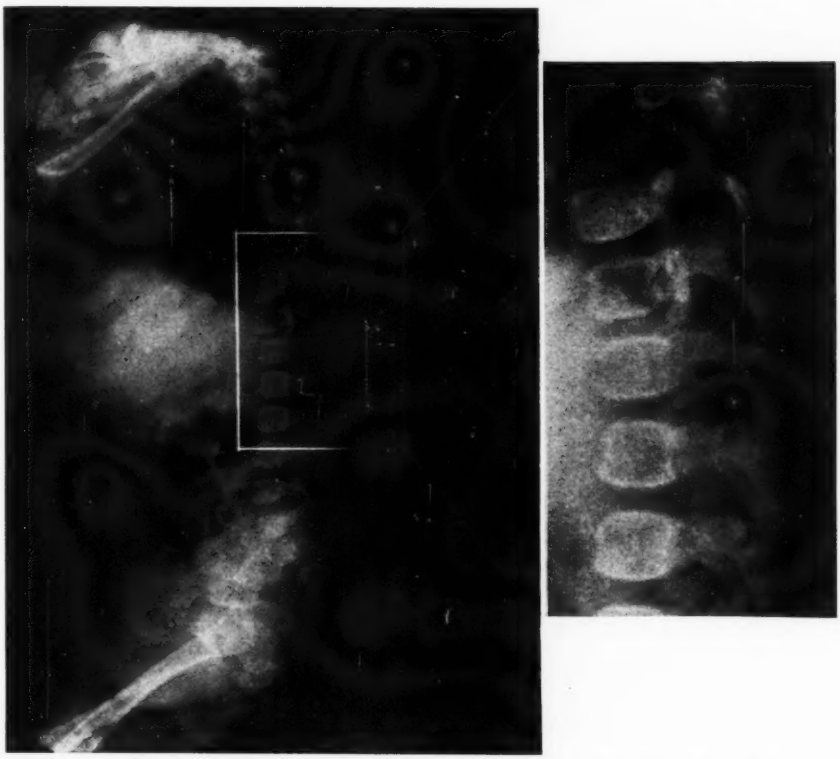

FIG. 1. Preoperative roentgenogram of spine. The area in which dilatation of the spinal canal was noted is shown in the enlargement on the right.

tion. The pathologist, following microscopic examination of the tissue, felt that the lesion represented a myelocytoma (lymphocytoma). In light of this finding bone marrow studies were done. The hematologist felt that the bone marrow studies were compatible with lymphatic leukemia. At time of last examination on June 13, 1949, 65 days after operation, the patient showed no signs of neurologic disorder.

## COMMENT

The 23 previously recorded instances in which an intraspinal tumor has been diagnosed during the first year of life are summarized in Table 1. The predominant

## TABLE 1

*Spinal tumors diagnosed during first year of life*

| Type | Author | Year | Age | Location | Remarks |
|---|---|---|---|---|---|
| Lipoma | Johnson[19] | 1856 | 10 mos. | Sacral | Excision of tumor through pre-existing aperture in sacrum. Complete recovery. |
| Lipoma | Témoin[28] | 1892 | 9 mos. | Sacral | Tumor almost exclusively superficial. No neurologic signs. |
| Lipoma | Témoin[28] | 1892 | 8 mos. | Lumbar | Removal of tumor connected to spinal canal by two pedicles. Recovery. |
| Lipoma | Wolbach & Millet[29] | 1913 | 10 mos. | Entire cord | Tumor intra- & extramedullary. Diagnosed at autopsy. |
| Lipoma | Bielschowsky & Valentin[7] | 1927 | 1 yr. | Lumbar | Associated hydrocephalus, hermaphroditism, spina bifida. Died of pneumonia. Diagnosed at autopsy. |
| Lipoma | Baker & Adams[5] | 1938 | 1 yr. | Entire cord, base of brain, choroid plexus | Associated hydrocephalus and dehydration. Diagnosed at autopsy. |
| Dermoid | Virchow[27] | 1857 | Stillborn | Lumbosacral | Stillborn hydrocephalic. |
| Dermoid | Muscatello[22] | 1894 | 5 mos. | D4 & L4–5 | Diagnosed at autopsy. |
| Dermoid | Ivanoff[18] | 1903 | Stillborn | Entire cord and medulla | Stillborn anencephalic monster. |
| Dermoid | Hansmann[15] | 1926 | 1 day | Conus | Died of bronchopneumonia on day after repair of harelip & cleft palate. Diagnosed at autopsy. |
| *Teratoid | Bailey & Ingraham[4] | 1947 | 1 mo. | Sacral | Associated dermal sinus. Laminectomy. Improvement. |
| *Teratoid | Bailey & Ingraham[4] | 1947 | Birth | Cauda | Laminectomy. Improvement. |
| †Teratoid | Ingraham & Bailey[17] | 1946 | 4 mos. | Cervical | Laminectomy & removal of cystic tumor. No recurrence 3½ yrs. postop. |
| Teratoid | Black & German[8] | 1950 | 10 mos. | D12 to L4 | "Pilonidal dimple" in sacral region & telangiectasis over L2-3 vertebrae with overgrowth of hair. Laminectomy. Improvement. |
| †Teratoma | Ingraham & Bailey[17] | 1946 | 1 yr. | Lumbar | Associated occult spina bifida. Laminectomy & incomplete removal of tumor. No recurrence 3½ yrs. postop. |
| Teratoma | Ingraham[16] | 1938 | 10 wks. | C2–7 | Associated wry neck. Queckenstedt test: block. Laminectomy & removal of tumor. Improvement neurologically. Died of pneumonia 6 mos. postop. |
| Teratoma | Black & German[8] | 1950 | 5 mos. | Foramen magnum to S2 | 3 laminectomies in 5 weeks. Marked improvement neurologically but had chronic urinary tract infection. Died of renal failure 9½ yrs. postop. |
| Sarcoma | Bruns[10] | 1908 | 9 mos. | Cervica | Hour-glass tumor. Diagnosed at autopsy. |
| Sarcoma | Luce[21] | 1908 | 6 mos. | D5–9 | Hour-glass tumor. Diagnosed at autopsy. |
| Sarcoma | Weill-Halle, Vogt, Duhem & Dubost[28] | 1932 | 1 yr. | D8–10 | Lumbar puncture: albumino-cyto'cgic dissociation. Cisternal puncture: 3 lymphocytes & negative Pandy. Cisternal lipiodol: arrested at D10 vertebra. Presumed to be sarcoma since neurologic signs receded after x-ray therapy. |
| Neurofibroma | Elliott[12] | 1884 | 2 mos. | Thoracic | Intramedullary tumor. Associated talipes varus. Diagnosed at autopsy. |
| Neuroblastoma | Anitschkow[2] | 1913 | 4 mos. | Lumbar | Hour-glass tumor. Laparotomy; death. |
| Intramedullary glioma | Klackenberg[20] | 1944 | 11 mos. | Cervical and thoracic | Spastic torticollis with paresis of upper extremities. Lumbar puncture: clear fluid, 4 lymphocytes & 2+ Pandy. Clinical diagnosis: encephalitis. Queckenstedt: normal. Diagnosed at autopsy. |
| Leukemic deposits | Mosberg | 1951 | 5 mos. | D11 to L1 | Laminectomy & partial removal of tumor. Improvement. |

* Quoted from Sachs and Horrax.[24]

† Since it was necessary to use the nomenclature of Sachs and Horrax in quoting the cases reported by Bailey and Ingraham in 1947, the same nomenclature is employed here in connection with the cases reported by Ingraham and Bailey in 1946.

tumor in this group is the lipoma, which comprises 6 of the 23 cases. Four cases of dermoid, 4 of teratoid, 3 of teratoma, 3 of sarcoma, and 1 each of neurofibroma, neuroblastoma and intramedullary glioma make up the remainder of the series. To these is added the case here reported, making a total of 24. Of these 24 cases, one-half have been diagnosed before death, and in 11 the tumor has been attacked surgically. It is of interest to note in this group the high incidence of associated anomalies: hydrocephalus, hermaphroditism, spina bifida, anencephalus, harelip, cleft palate, wry neck, talipes varus, "pilonidal dimple" and telangiectasis with overgrowth of hair.

Myelography may be employed to aid in localization of the lesion but dilatation of the spinal canal as shown on the plain roentgenograms is a valuable sign when present.

The age of these patients should not contraindicate operation when the integrity of the intraspinal structures is endangered. The excellent operative results obtained by Ingraham and Bailey[4,16,17] and the case reported by Black and German[8] in which 3 operations were performed to remove a tumor which extended throughout almost the entire spinal canal have demonstrated the feasibility of treating these children surgically.

There are of course many unreported cases, some of which have undoubtedly been successfully treated surgically. Sachs,[23] in reviewing his series of 235 verified spinal tumors, has found 3 cases which would fall into the group discussed in this paper—an astrocytoma in a 1-year-old child, an extradural sarcoma in a child of 5 months, and an intramedullary astrocytoma in a 1-year-old child.

It does not lie within the scope of this communication to discuss the neurologic manifestations of leukemia. The reader is referred to the papers by Critchley and Greenfield,[11] Schwab and Weiss,[25] and Bass,[6] which respectively deal with spinal symptoms of leukemia, neurologic aspects of leukemia, and the neurologic manifestations of leukemia in children. None of these authors mentions a spinal tumor in a patient under 1 year of age.

## SUMMARY

The case is reported of a 5-month-old child who became paraplegic within a period of 4 weeks and whose symptoms were relieved by laminectomy and partial removal of an extradural thoracolumbar leukemic deposit. The patient was subsequently found to be suffering from lymphatic leukemia.

The literature concerning intraspinal tumors diagnosed during the first year of life is briefly reviewed.

The author is indebted to Dr. John Wagner for the pathologic studies and to Dr. Milton Sacks for the hematologic studies.

## REFERENCES

1. Adson, A. W. Intraspinal tumors; surgical consideration. Collective review. *Int. Abstr. Surg.*, 1938, *67:* 225–237.
2. Anitschkow, N. Zur Kenntnis der malignen Neuroblastome des N. sympathicus. *Virchows Arch.*, 1913, *214:* 137–149.
3. Antoni, N. R. E. Über Rückenmarkstumoren und Neurofibrome. Studien zur pathologischen Anatomie und Embryogenese (mit einem klinischen Anhang). *München: J. F. Bergmann*, 1920, 435 pp.
4. Bailey, O. T., and Ingraham, F. D. Quoted by Sachs, E., Jr., and Horrax, G.[24]
5. Baker, A. B., and Adams, J. M. Lipomatosis of the central nervous system. *Amer. J. Cancer*, 1938, *34:* 214–219.

6. Bass, M. H. Leukemia in children, with special reference to lesions in the nervous system. *Amer. J. med. Sci.*, 1921, n.s. *162:* 647–654.
7. Bielschowsky, M., and Valentin, B. Ueber ein Lipom am Rückenmark mit Hydrosyringomyelie und anderen Missbildungen. *J. Psychol. Neurol., Lpz.*, 1927, *34:* 225–233.
8. Black, S. P. W., and German, W. J. Four congenital tumors found at operation within the vertebral canal with observations on their incidence. *J. Neurosurg.*, 1950, *7:* 49–61.
9. Boldrey, E. B., and Elvidge, A. R. Dermoid cysts of the vertebral canal. *Ann. Surg.*, 1939, *110:* 273–284.
10. Bruns, L., Cramer, A., and Ziehen, Th. Handbuch der Nervenkrankheiten im Kindesalter. *Berlin: S. Karger*, 1912, 980 pp. (see p. 301).
11. Critchley, M., and Greenfield, J. G. Spinal symptoms in chloroma and leukaemia. *Brain*, 1930, *53:* 11–37.
12. Elliott, G. R. Neuro-fibroma complicating spina bifida. *Med. Rec., N.Y.*, 1884, *25:* 194–195.
13. Ford, F. R. Diseases of the nervous system in infancy, childhood and adolescence. *Springfield, Ill.: Charles C Thomas*, 1944, 2nd ed., 1143 pp. (see p. 840).
14. Hamby, W. B. Tumors in the spinal canal in childhood: an analysis of the literature with report of a case. *J. nerv. ment. Dis.*, 1935, *81:* 24–42.
15. Hansmann, G. H. A congenital cystic tumor of the neurenteric canal with special reference to its histology and pathological significance. *Surg. Gynec. Obstet.*, 1926, *42:* 124–127.
16. Ingraham, F. D. Intraspinal tumors in infancy and childhood. *Amer. J. Surg.*, 1938, n.s. *39:* 342–376.
17. Ingraham, F. D., and Bailey, O. T. Cystic teratomas and teratoid tumors of the central nervous system in infancy and childhood. *J. Neurosurg.*, 1946, *3:* 511–532.
18. Ivanoff, N. J. Quoted by Boldrey, E. B. and Elvidge, A. R.[9]
19. Johnson, A. Fatty tumour from the sacrum of a child, connected with the spinal membranes. *Trans. path. Soc. Lond.*, 1857, *8:* 16–18.
20. Klackenberg, G. Ueber Rückenmarksgeschwülste im Kindesalter, im Anschluss an einen Fall von intramedullärem Gliom bei einem einjährigen Kinde. *Ann. Paediat.*, 1944, *163:* 183–198.
21. Luce. [*Report of case*] *Neurol. Zbl.*, 1908, *27:* 791–792.
22. Muscatello, G. Ueber die angeborenen Spalten des Schädels und der Wirbelsäule. *Arch. klin. Chir.*, 1894, *47:* 257–301.
23. Sachs, E. Personal communication.
24. Sachs, E., Jr., and Horrax, G. A cervical and a lumbar pilonidal sinus communicating with intraspinal dermoids. Report of 2 cases and review of the literature. *J. Neurosurg.*, 1949, *6:* 97–112.
25. Schwab, R. S., and Weiss, S. The neurologic aspect of leukemia. *Amer. J. med. Sci.*, 1935, n.s. *189:* 766–778.
26. Témoin, D. Lipome périméningé simulant un spina bifida. *Arch. prov. Chir., Paris*, 1892, *1:* 179–183.
27. Virchow, R. Ueber eine eigenthümliche Geschwulst in dem unteren Ende der Wirbelsäule eines todtgebornen Mädchens. *Mschr. Geburtsh. Frauenkrankh.*, 1857, *9:* 259–262.
28. Weill-Halle, B., Vogt, C., Duhem, and Dubost. Tumeur pulmonaire et médullaire (sarcome probable) chez un enfant de 1 an. Traitement radiothérapique efficace. *Bull. Soc. Pédiat. Paris*, 1932, *30:* 513–522.
29. Wolbach, S. B., and Millet, J. A. P. Diffuse sub-dural lipomatosis of the spinal cord in an infant. *Boston med. surg. J.*, 1913, *168:* 681–682.

# PARADOXIC BRAIN ABSCESS IN CONGENITAL HEART DISEASE

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Paradoxic brain abscess is the name given to a certain form of metastatic abscess occurring in patients without pulmonary suppuration, but with congenital cardiac defects permitting venous blood to circulate in the arterial system without passing through the lungs.

This type of brain abscess is rare, presumably because of the combination of factors that must exist before such lesions can develop. Compared with metastatic abscesses arising from chronic suppuration in the lungs, Ruhberg[18] found that a paradoxic abscess occurred once for every 13 cases of metastasis from lung disease. The rarity of the condition is further emphasized by Hanna,[10] who recorded 6 cases of paradoxic abscess in 160 fatal cases of congenital cardiac disease. Robbins[17] found almost the same proportion (3 in 53), but Abbott's[1] percentage was much lower (7 in 1000).

Only 39 cases of paradoxic brain abscess could be found reported in the literature.[2–9,11–16,19–22] Largely because of failure to recognize this condition and the extremely rapid course in some of these patients, they fared almost uniformly badly. Up to the present time, only 1 patient has been cured. This report deals with a patient who is apparently well 1 year after treatment.

## CASE REPORT

The patient was a college student, aged 22 years. She first came to the Mount Sinai Hospital in 1946, with signs of a generalized infection. A complete investigation at that time established the diagnosis of subacute bacterial endocarditis (endarteritis?). The basic cardiac lesion was tetralogy of Fallot with a patent ductus arteriosus, confirmed by angiocardiography. The infection responded well to penicillin treatment, and she was discharged, apparently cured. She had no further complaints until November, 1948, when a routine dental prophylaxis was carried out. Four days later she complained of malaise, nausea and chills; her temperature was 101°. For the next week she continued to run a low-grade fever and complained of headache. The day prior to admission she had what was apparently a generalized convulsion. No antibiotics were given before or after the dental work. A blood culture taken by her physician was negative.

*Examination.* Temperature was 100.4°, pulse rate 100, and B.P. 110/74. There was pronounced cyanosis. A continuous, to-and-fro, machinery-like murmur was heard at the pulmonic area; there was a thrill at the pulmonic area and at Erb's point. A severe kyphoscoliosis was noted. The tip of the spleen was just palpable. She showed some drowsiness and loss of recent memory. There was repeated vomiting, and she complained of severe headache, worse on the right side. There was a Babinski sign bilaterally, with transient bilateral ankle clonus. On double simultaneous stimulation a left hemihypesthesia, without astereognosis was noted. There was early papilledema bilaterally, worse on the right, with marked venous engorgement. A complete left homonymous hemianopsia was found. There was bilateral periorbital edema and tenderness in the right frontotemporal region.

Hb. was 15.9 gm. WBC was 19,400, with a shift to the left. Sedimentation rate was normal on two occasions. Repeated blood cultures were sterile. X-ray of the skull showed no abnormality. EEG showed a large amount of very slow (1–2/sec) activity in the right posterior temporal region. A lumbar puncture yielded clear, colorless fluid, under a pressure of 220 mm.; it was otherwise normal. The blood and CSF Wassermann reaction was negative. X-ray of the

chest showed the typical boot-shaped heart of tetralogy of Fallot and marked kyphoscoliosi (Fig. 1).

A *diagnosis* of brain abscess was made and she was transferred to the neurosurgical service

*Treatment.* Penicillin (aqueous procaine penicillin, 600,000 units a day) was started at th time of admission and given continuously thereafter. For a while it appeared that penicillin alone was going to control the infection. About 2 weeks later, however, the papilledema increased, the EEG abnormality became more pronounced, and the neurological signs advanced.

*1st Operation.* On Jan. 4, 1949 the senior author made a burr hole in the right tempora bone. With the exploring needle, an abscess cavity was encountered in the right temporal lobe, and 5 cc. of thick yellowish-white, odorless pus were aspirated. The abscess was not encapsulated and at one time the needle, of its own weight, fell into the temporal horn of the lateral ventricle. Penicillin solution was instilled into the cavity and the wound closed without drainage. A culture of the pus yielded no growth, and no organisms were seen on direct smear.

FIG. 1. X-ray of the chest, showing typical heart shadow.

*Course.* For the next few days, the papilledema appeared to be receding and the patient felt well, but she soon complained of severe headache and began to vomit. The abscess was again aspirated and 5 cc. of thick reddish pus were obtained. Into the abscess cavity penicillin solution and 1 cc. of pantopaque (R) were injected.

X-rays of the skull taken after this procedure showed a spherical mass of pantopaque (R), about 1.5 cm. in diameter, deep in the right temporal lobe; droplets of pantopaque could be seen scattered throughout the ventricular system (Fig. 2).

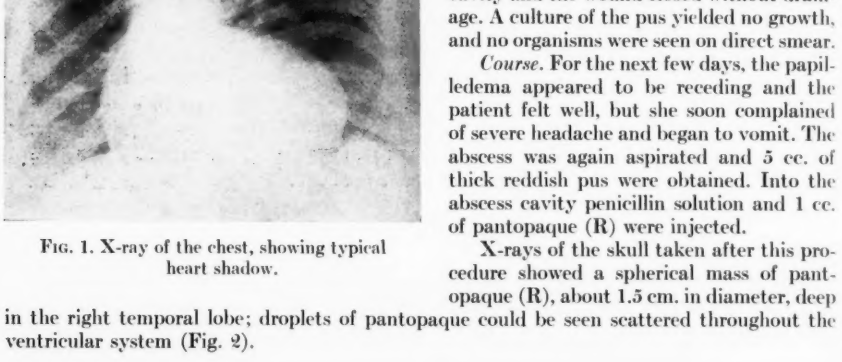

FIG. 2. Showing pantopaque in the right temporal lobe and scattered droplets in the ventricles.

The next day the patient felt worse; she continued to vomit and the papilledema increased.

*2nd Operation.* The following day a right temporal craniotomy was performed by Dr. Cohen and the abscess was entered through a transcortical incision in the inferior portion of the temporal lobe. The brain was very tense, and there was no capsule. There seemed to be several pockets within the abscess, each containing pus of a slightly different color and consistency. The entire abscess and the softened necrotic brain tissue surrounding it were removed by suction. A drain was placed in the cavity and brought out through a separate posterior stab wound.

*Postoperative Course.* This was discouraging at first, and there was little hope of her survival. The CSF was purulent and under great pressure for a long time after operation, and she required daily lumbar punctures to reduce the tense, bulging decompression. The EEG showed what appeared to be a larger focus of abnormality, and, with the other signs, led us to suspect multiple cerebral abscesses. For this reason, a pneumoencephalogram was performed.

The films (Fig. 3) showed only the distortion corresponding to the area of the original abscess. Antibiotic systemic therapy was continued. Eventually she felt better and the signs receded.

FIG. 3. Displaced ventricular system.

When penicillin was discontinued and there was no recurrence, she was discharged, apparently well, 4 months after admission. Her vision was moderately reduced and the fundi presented the picture of post-papilledema optic atrophy. There was a left homonymous hemianopsia, with some sparing of the upper left temporal field. A mild hemisensory loss was present, but there was no weakness.

When examined last, 1 year after discharge, she had essentially the same findings. The fundi had reverted almost to normal. She complained only of difficulty in walking out-of-doors, owing to the visual field defect. There was no evidence of infection. She was attending regular classes at a university and doing well in her studies.

## DISCUSSION

A review of the literature indicates that paradoxic brain abscess has been found in 40 cases, including this one. We have arbitrarily eliminated 1 case so diagnosed, because generalized sepsis was present. Of this number, only 8 were recognized before death, 7 of them receiving suitable treatment.

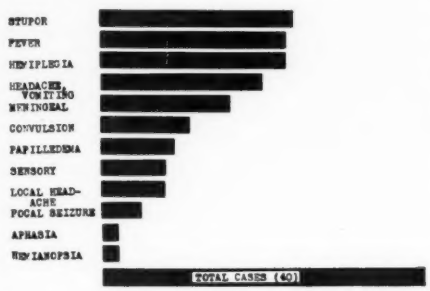


FIG. 4. Symptoms and signs in the 40 collected cases.

Fig. 4 shows that in a good proportion of cases there was ample reason to suspect a localized process in the brain. Convulsions, generalized or focal, occurred in 11 cases, hemiparesis or its equivalents in 23, signs of increased intracranial pressure in 20, and meningeal signs in 17. It is sig-

nificant that well over half the patients were stuporous at the time of admission this may account for the fact that although there were 11 abscesses in the occipital lobes and 10 in the temporal, hemianopsia was reported only twice in the entire group. Aphasia, also, was mentioned in only 2 cases, although there was a total of 10 abscesses involving the dominant temporal or parietal lobes. Sensory changes were recorded in only 8 cases.

The laboratory findings are summarized in Fig. 5. The white blood count was elevated in 11 cases, and reported as normal in only 3. Blood cultures were negative in every case where this was done. The exact location of the abscess given by electroencephalography in our case made it unnecessary to do air studies. Most of the cases were reported before electroencephalography had reached its present refinement, and we can find a report of its having been done in only 1 case;[8] there was diffuse slow activity, without any localizing characteristics. The cerebrospinal fluid

FIG. 5. Laboratory findings in 40 collected cases.

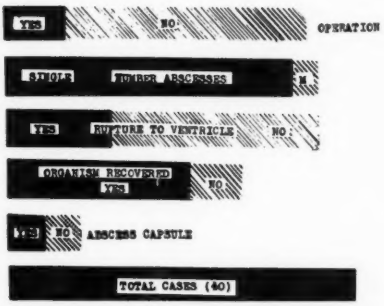


FIG. 6. Some characteristics of the abscesses in 40 collected cases.

was abnormal at some stage of the disease in almost every case in which such an examination was reported.

It is evident from the clinical observations in this series of cases that in every patient with congenital heart disease in which there is a right-left shunt (manifested by transient or permanent cyanosis), the development of any signs of central nervous system disease should raise the suspicion of brain abscess and immediate steps should be taken to establish the diagnosis and institute treatment.

Fig. 6 shows some of the characteristics of these abscesses as encountered at operation or postmortem examination. Paradoxic abscesses are almost always single, and in only 3 of the entire series was there more than one in the brain. Like other types of metastatic abscess, paradoxic lesions are rarely encapsulated; in 4 of the 40 cases there was a definite capsule, although the lack of it was actually mentioned in only 4. This absence of encapsulation undoubtedly accounts for the tendency of these lesions to rupture into the ventricles and the subarachnoid space; evidence of intraventricular rupture was found in 12 cases, although in 24 others it had definitely not occurred. Organisms could be recovered from most of these lesions. In our case, failure to culture bacteria from the abscess was attributed to penicillin given prior to the operation.

No preference for either side or any particular part of the brain was found in any of the reported cases, as shown in Fig. 7.

The treatment of paradoxic brain abscess is essentially a surgical problem, and the principles that apply to intracranial suppuration in general will hold in these cases. The liberal use of penicillin and, when indicated, other antibiotics, locally and systemically, is obvious.

Two cases previously reported from this hospital by Wechsler and Kaplan[22] were correctly diagnosed, and, although adequate surgical treatment was undertaken, the patients died. Had penicillin and the newer antibiotics been available, they might have survived.

A patient of Grant's reported by Hand[9] was operated upon and apparently cured, but she died 6 weeks later of an abscess in another part of the brain.

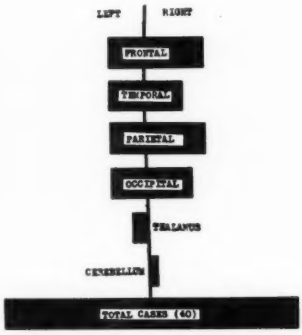


FIG. 7. Site of the abscess in 40 collected cases.

FIG. 8. Type of heart lesions and duration of life from onset of abscess in 40 collected cases.

The patient of Smolik, Blattner and Heys[20] was cured by surgical drainage and sulfonamides, and represents the sole survival up to this time.

The best treatment, in view of all these observations, would seem to be prophylactic. Fig. 8 demonstrates that some antecedent illness was recorded in half of the cases in the literature in which the history was sufficiently detailed. The same precautions should be taken as for the prevention of bacterial endocarditis in rheumatic or congenital cardiac patients when a procedure such as tonsillectomy or tooth extraction is undertaken. It is conceivable that one injection of a long-acting penicillin preparation would have prevented this complication in our patient.

Most of the patients died soon after the onset of cerebral symptoms, half of them within 2 weeks.

A great deal has been written about paradoxic *embolism* in congenital heart disease. Unfortunately, its occurrence has been overemphasized in contrast to abscess, which, unlike embolism, is potentially curable. Hanna,[10] for example, in 160 fatal cases of congenital cardiac disease, found only 1 case of paradoxic embolism, whereas there were 6 of brain abscess. Abbott[1] found 13 instances of embolism and 7 of abscess in her 1000 cases.

The pathogenesis of paradoxic cerebral abscess has occupied considerable space in the literature. Various theories, all without adequate proof, have been advanced. Transient bacteremia must occur, and organisms must pass through with the venous blood, from the right to the left side of the heart, thus escaping the normal filtering or phagocytic action of the lung capillaries, and reaching the brain. It is significant, however, that in the recorded cases there were rarely abscesses in other organs, despite large right-left shunts.

There is some evidence to show that these patients have some form of pre-existing cerebral disease, whatever the cause. In Abbott's[1] cases of tetralogy of Fallot, for example, cerebral disease was considered the primary cause of death in 15 per cent of the patients, and this figure was only slightly exceeded by cardiac insufficiency. Episodes of unconsciousness and convulsions are not unusual in patients with congenital heart disease, and in 2 of the reported cases of paradoxic abscess there was a history of such attacks for a much longer time than an abscess could have existed.

As far as actual knowledge is concerned, however, we know very little more than we did in 1850, when Ballet[5] presented the first collected series of cases of this type. We should, therefore, like to borrow his conclusions. "As to the mechanism by which an abnormal communication between the chambers of the heart favors the development of cerebral suppuration, this is for the time being a matter of pure speculation, and any number of guesses might be made . . . . These theories are seductive because in the present state of affairs there is no proof that they are right or wrong. We should do better, for the time being, to stick to the clinical facts."

## ADDENDUM

Since this paper was submitted for publication, two additional series of cases have appeared in the literature. The first* records 2 cases, only 1 of which was verified. In this instance a right temporal lobe abscess due to hemolytic staphylococcus albus was responsible for the death of a patient with an interventricular septal defect and advanced pulmonary tuberculosis. Death occurred rapidly and there was no opportunity for adequate diagnostic study or treatment. Their other patient died, but permission for postmortem examination was not obtained. There is a comprehensive review of the literature.

The second report† deals with 9 new cases from routine autopsy material. The cardiac and cerebral lesions were similar to those previously described in the literature.

## REFERENCES

1. Abbott, M. E. Atlas of congenital cardiac disease. *New York: American Heart Association*, 1936, x, 62 pp.
2. Abbott, M. E., Lewis, D. S., and Beattie, W. W. Differential study of a case of pulmonary stenosis of inflammatory origin (ventricular septum closed) and two cases of (a) pulmonary stenosis and (b) pulmonary atresia of developmental origin with associated ventricular septal defect and death from paradoxical cerebral embolism. In three cases, aged respectively, fourteen, ten and eleven years. *Amer. J. med. Sci.*, 1923, n.s. *165:* 636–659.

* Sancetta, S. M., and Zimmerman, H. A. Congenital heart disease with septal defects in which paradoxical brain abscess causes death. A review of the literature and report of two cases. *Circulation*, 1950, *1:* 593–601.

† Maronde, R. F. Brain abscess and congenital heart disease. *Ann. intern. Med.*, 1950, *33:* 602–606.

3. Acker, G. N. A case of cardiac anomaly. *Arch. Pediat.*, 1895, *12:* 828–833.
4. Bach, F. A case of congenital morbus cordis studied over a period of twelve years. *Lancet*, 1928, *1:* 1009–1011.
5. Ballet, G. Des abcès du cerveau consécutifs à certaines malformations cardiaques. *Arch. gén. Méd.*, 1880, *145:* 659–667.
6. Baumgartner, E. A., and Abbott, M. E. Interventricular septal defect with dextroposition of aorta and dilatation of the pulmonary artery ("Eisenmenger complex") terminating by cerebral abscess. Report of a case observed during life, presenting impaired conduction, and paralysis of recurrent laryngeal nerve from pressure of hypertrophied pulmonary conus. *Amer. J. med. Sci.*, 1929, n.s. *177:* 639–647.
7. Deneke, T. Zur Röntgendiagnostik seltenerer Herzleiden. *Dtsch. Arch. klin. Med.*, 1906, *89:* 39–66.
8. Gates, E. M., Rogers, H. M., and Edwards, J. E. The syndrome of cerebral abscess and congenital cardiac disease. *Proc. Mayo Clin.*, 1947, *22:* 401–412.
9. Hand, A. Cerebral abscess: a complication of congenital cardiac disease (Fallot's tetralogy). Report of two cases with diagnosis and operation. *J. Pediat.*, 1947, *31:* 662–668.
10. Hanna, R. Cerebral abscess and paradoxic embolism associated with congenital heart disease. Report of seven cases, with a review of the literature. *Amer. J. Dis. Child.*, 1941, *62:* 555–567.
11. Heigel, A. Über eine besondere Form von Entwicklungsstörung der Trikuspidalklappe. *Virchows Arch.*, 1913, *214:* 301–319.
12. Ingham, D. W. Paradoxical embolism. *Amer. J. med. Sci.*, 1938, n.s. *196:* 201–207.
13. Jacobi, A. Patent ventricular septum in a man of twenty-nine years. *Arch. Pediat.*, 1895, *12:* 834–838.
14. Northrup, W. P. Congenital pulmonary stenosis (conus arteriosis)—incompleteness of septum ventriculorum—cyanosis—abscess of brain—death at four and a half years (specimen shown). *Trans. Amer. Pediat. Soc.*, 1894, *6:* 76–79.
15. Raab, W. Untersuchungen über einen Fall von kongenitalem Herzvitium. *Wien. Arch. inn. Med.*, 1923, *7:* 367–380.
16. Rabinowitz, M. A., Weinstein, J., and Marcus, I. H. Brain abscess (paradoxical) in congenital heart disease. *Amer. Heart J.*, 1932, *7:* 790–795.
17. Robbins, S. L. Brain abscess associated with congenital heart disease. *Arch. intern. Med.*, 1945, *75:* 279–283.
18. Ruhberg, G. N. Metastatic brain abscesses. *Min. Med.*, 1942, *25:* 108–113.
19. Sidenberg, S. S., Kessler, M. M., and Wolpaw, R. A case of tetralogy of Fallot with absence of cerebellar vermis. Termination by brain abscess. *J. Pediat.*, 1946, *28:* 719–728.
20. Smolik, E. A., Blattner, R. J., and Heys, F. M. Brain abscess associated with congenital heart disease. Report of a case with complete recovery. *J. Amer. med. Ass.*, 1946, *130:* 145–147.
21. Stone, W. H. A case of tricaelian heart with insufficiency of the ventricular septum. *St. Thomas Hosp. Rep.*, 1882, n.s. *11:* 57–60.
22. Wechsler, I. S., and Kaplan, A. Cerebral abscess (paradoxic) accompanying congenital heart disease. Report of two cases. *Arch. intern. Med.*, 1940, *66:* 1282–1289.

## INTRANASAL ENCEPHALOCELE

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Encephalocele, or congenital protrusion of the brain and meninges through the skull, is not uncommon. The most frequent site of such a lesion is occipital. Ingraham and Matson[7] reported a series of 84 encephaloceles, of which 63 were occipital, 9 parietal, 6 frontal, 5 nasal, and only 1 presenting through a defect in the cribriform plate into the nasopharynx.

Fenger[3] stated that of the anterior herniations, the so-called sincipital type is the more frequent, in which an external mass presents itself at the nasion in the midline, or laterally at the junction of cartilaginous and bony portions of the nose, or at the

inner canthus of the eye. These have been designated respectively as nasofrontal nasoethmoid, and nasoorbital by von Meyer.[9] The so-called basal type, in which an external mass is not present, is much less frequent. Heineke[6] classifies them as sphenopharyngeal, in which the mass presents in the nasal or nasopharyngeal cavity; sphenoorbital, in which the herniation occurs through the superior orbital fissure into the orbit, causing pulsating exophthalmos; or sphenomaxillary, in which the herniation passes through the inferior orbital fissure into the pterygopalatine fossa.

Since an external mass is present, the sincipital type is readily recognized. Funkhouser[4] reported 3 previous cases of this type and added another of his own which Dr. Charles Dowman corrected successfully by means of an intracranial approach. Mood[10] reviewed 17 cases and added 1 of his own in which external removal was successful.

In the sphenopharyngeal or intranasal type of encephalocele, no external tumor is visible, the mass presenting in the nasal cavity. Ingraham and Matson's[7] patient had, in addition, a harelip and cleft palate and the mass was visible through the palatal defect. Successful intracranial closure of the defect in the cribriform plate was carried out. Anderson[2] reported 1 case cured by intracranial approach and included an excellent review of the literature. Adson and Uihlein,[1] in reporting 18 cases of spontaneous rhinorrhea, stated that nasal polyps were observed in 11 cases and concluded that nasal polyps fairly frequently are nasal meningoceles. In none of the reported cases was the intranasal tumor actually removed through the intracranial approach, each author using slightly different technique to close the dural and bony defect, and leaving the intranasal mass to atrophy spontaneously.

The following are 2 pertinent examples of true intranasal encephalocele.

## CASE REPORTS

*Case 1.* J. K., a 5-year-old white male, was admitted to the Neurosurgical Service on Aug. 25, 1948 because of a tumor mass in the right nasal cavity and a discharge of clear fluid from the right nostril. At the age of 9 months, a "nasal polyp" had been removed with a snare and the fluid leakage had been continuous since that time. It had again been removed with a nasal snare 5 weeks before admission, after which the discharge had become more profuse, and had caused excoriation of the right nares and upper lip. Amazingly enough, the child had never had meningitis.

*Examination.* There was a broadening of the bridge of the nose, a slight internal strabismus but no extraocular muscle palsy, and intermittent discharge of clear fluid from the right nostril (Fig. 1). Within the right nasal cavity was a rather large grey glistening mass with bluish streaks across its surface. X-rays of the skull (Fig. 2) revealed a broad nasion and a soft-tissue tumor mass filling the right nasal cavity.

*Operation.* On Aug. 28, 1948, under endotracheal anesthesia, a right frontal bone flap was turned, using a coronal skin incision. An intradural approach was first made, disclosing the meninges and cerebral tissue of the right frontal lobe passing into the nose through a funnel-shaped defect in the cribriform plate measuring 1.5×0.5 cm. in diameter. The stalk of the encephalocele was transected and an attempt at intradural suture of the dural defect was made. A water-tight dural closure could not be accomplished, so an extradural approach was then made, and a piece of gelfoam, followed by a large piece of temporal muscle, followed by another piece of gelfoam was packed into the funnel-like bony defect. An additional piece of gelfoam was placed over the suture line intradurally and routine closure carried out.

*Course.* The child received penicillin daily before and after surgery. His course was uneventful, and he was dismissed on the 12th postoperative day. There was no discharge from the nose following surgery, and it had not recurred when the patient was seen 14 months after operation. The mass was still present in the right nasal cavity, somewhat reduced in size, and not causing symptomatic nasal obstruction.

FIG. 1 (*left*). Preoperative photograph of Case 1 showing broad nose and rhinorrhea.
FIG. 2 (*right*). Preoperative x-ray of Case 1 showing intranasal soft tissue mass.

*Case 2.* P. J., a 4-year-old white female, was admitted to the Pediatric Service on Mar. 14, 1950 because of drainage of clear fluid from the nose. Two years previously she had fallen from a third-story window and sustained a linear skull fracture, which on x-ray was seen to extend into the right ethmoid region. A temporary rhinorrhea had occurred with this injury, but had subsided spontaneously in a few days. One year later, she had fallen out of a moving car and sustained a linear fracture of the occipital bone. Rhinorrhea did not follow this injury. Six weeks before admission pneumococcic meningitis developed, which was cured with penicillin, aureomycin, and sulfadiazine. The only post-meningitic residuals were impaired

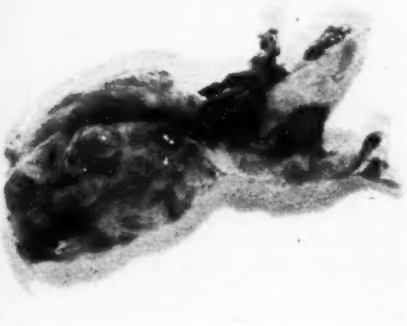

FIG. 3. (*left*). Operative photograph showing the encephalocele grasped by pituitary forceps, having been delivered from the nasal cavity through the defect in the cribriform plate (Case 2).
FIG 4 (*right*). Nasal encephalocele removed through intracranial approach (Case 2).

hearing bilaterally, and an intermittent drainage of clear fluid from the nose. On the day of admission, she had been examined by the referring otorhinolaryngologist because of her deafness. He had found a greyish mass of tissue high in the right nasal cavity, and on manipulation of the mass, clear fluid was seen to drain from it.

*Examination.* Positive findings were: bilateral deafness, the above-mentioned mass in the right nasal cavity, and profuse drainage of clear CSF from the right nostril. X-rays revealed cloudiness of the right nasal cavity, but no defect could be demonstrated in the right cribriform plate.

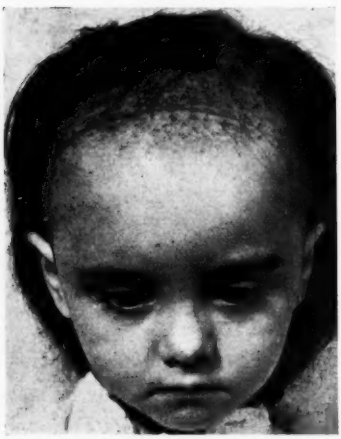

FIG. 5. Case 2, on 6th postoperative day.

*Operation.* On Mar. 18, 1950, under endotracheal anesthesia, a right frontal bone flap was turned, using a coronal skin incision. An extradural approach was made to the olfactory area. A bony defect was present in the right cribriform plate, 1.5×0.5 cm. in diameter, through which the dura continued on into the nose. While isolating the stalk of the dural projection, the tumor mass within the nasal cavity began to deliver itself into the wound, and with gentle traction the entire encephalocele was extracted through the defect and brought into the cranial cavity (Fig. 3). It was then readily amputated and water-tight closure of the dura was easily accomplished. A bone graft of split frozen rib from the bone bank was fashioned to fit the defect in the cribriform plate and wedged firmly into its funnel-like opening. Penicillin solution was flushed extradurally throughout the wound, which was closed in a routine fashion.

*Microscopic Examination.* Edematous brain tissue lacking characteristic cortical pattern was seen along with the dural sac. Diagnosis: Intranasal encephalocele (Fig. 4).

*Course.* Penicillin was administered before and after surgery. There was no further drainage from the nose. Recovery was uneventful and she was dismissed on the 6th postoperative day (Fig. 5). When seen 3 months later, there had been no return of rhinorrhea, and deafness was the only complaint.

## COMMENT

In Case 1, the broad nose, the history of two attempts at removal of a nasal polyp, and the long history of rhinorrhea in the absence of head trauma made the diagnosis obvious. In Case 2, the surgeon (W.P.W.) assumed the rhinorrhea was simply traumatic, and had not anticipated the true nature of the lesion until its actual exposure at operation. The skull fracture had undoubtedly torn the base of the encephalocele to precipitate the initial onset of spinal fluid leakage.

As to technique of repair, various methods have been reported. Adson and Uihlein[1] advocate bilateral frontal approach with ligation of the sagittal sinus and section of the falx. They suggest extradural approach and have used animal membrane, bone wax, and tantalum to close the defect. Ingraham and Matson[7] also used a bilateral exposure. German[5] and Anderson[2] used a unilateral bone flap and advised intradural rather than extradural exposure, closing the defect with dural flaps. In none of the previously reported cases was the entire encephalocele delivered from the nose, each author advising against such a procedure for fear of infection, and each stating that the intranasal mass shrinks down to become asymptomatic. A discouragingly large intranasal mass still remains in our first patient, and though it

might easily be removed with a snare, we have not yet had the courage to do so for fear of breaking through the barrier of scar tissue at the cribriform area and causing recurrent rhinorrhea. Our Case 2 appears to be the only reported one in which the encephalocele was delivered in toto into the cranial cavity. This perhaps was unwise, and actually was not planned until it began to deliver itself into the wound. However, it resulted in markedly improved exposure, and made amputation of the sac, water-tight dural closure, and insertion of bone graft into the bony defect technically much easier. Chemotherapy was relied upon to prevent infection and successfully did so.

The otorhinolaryngologist must be on the alert for such lesions. The broad-based nose or history of spontaneous rhinorrhea will certainly aid in the diagnosis. Adson and Uihlein[1] quote Dr. Hallberg of the Section of Otolaryngology and Rhinology of the Mayo Clinic as stating that "the intranasal meningocele has a whitish look and makes its appearance in the nose between the septum and the middle turbinate. In this way they are differentiated from ordinary polyps, most of which originate in the middle meatus, that is, between the middle turbinate and the lateral wall of the nose." Certainly, once rhinorrhea occurs, intracranial repair is indicated.

## SUMMARY

Two cases of intranasal encephalocele with relief of rhinorrhea by intracranial approach are reported. A brief review of the literature is given, and technique of surgical repair is discussed. Intranasal encephalocele is probably more common than generally believed, and should be considered in the differential diagnosis of nasal polyp and rhinorrhea.

## REFERENCES

1. Adson, A. W., and Uihlein, A. Repair of defects in ethmoid and frontal sinuses resulting in cerebrospinal rhinorrhea. *Arch. Surg., Chicago*, 1949, *58:* 623–634.
2. Anderson, F. M. Intranasal (sphenopharyngeal) encephalocele. A report of a case with intracranial repair and a review of the subject. *Arch. Otolaryng., Chicago*, 1947, *46:* 664–654.
3. Fenger, C. Basal hernias of the brain. *Amer. J. med. Sci.*, 1895, n.s. *109:* 1–17.
4. Funkhouser, W. L. Encephalo-meningocele through the foramen cecum. *South. med. J.*, 1922, *15:* 385–387.
5. German, W. J. Cerebrospinal rhinorrhea—surgical repair. *J. Neurosurg.*, 1944, *1:* 60–66.
6. Heineke, W. Die chirurgischen Krankheiten des Kopfes. *Stuttgart: F. Enke*, 1882, xlii, 252 pp. (Cited by McGillicuddy.[8])
7. Ingraham, F. D., and Matson, D. D. Spina bifida and cranium bifidum. IV. An unusual nasopharyngeal encephalocele. *New Engl. J. Med.*, 1943, *228:* 815–820.
8. McGillicuddy, O. B. Encephalomeningoceles in the nasal cavities. *Ann. Otol., etc., St. Louis*, 1942, *51:* 516–525.
9. v. Meyer, E. Ueber eine basale Hirnhernie in der Gegend der Lamina cribrosa. *Virchows Arch.*, 1890, *120:* 309–320. (Cited by Fenger.[3])
10. Mood, G. F. Congenital anterior herniations of brain. *Ann. Otol., etc., St. Louis*, 1938, *47:* 391–401.

# ASTROCYTOMA GRADE III ASSOCIATED WITH PROFUSE SUBARACHNOID BLEEDING AS ITS FIRST MANIFESTATION

## CASE REPORT*

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Many reports in the literature suggest that cerebral neoplasms may cause subarachnoid bleeding.[2,3,4,6,8,9] In the majority of cases reported the amount of subarachnoid blood has been minimal. Recently, Echols and Rehfeldt[2] collected 4 cases of profuse subarachnoid hemorrhage due to malignant brain tumor in the American literature and added 1 case of their own. The case we wish to report is unique in that the history was brief and cerebral neoplasm was not suspected.

### CASE PRESENTATION

A 27-year-old, right-handed white male was first seen in a nearby Naval Hospital on Mar. 7, 1950. He had apparently been in good health until the morning of Mar. 6, 1950. On that day he was lifting a pig into a truck. The animal jumped unexpectedly, causing the patient to extend his head and neck quickly and forcibly. This precipitated a sharp frontal headache, which rapidly spread to involve the entire head, and stiffness of the neck. The headache was so severe that a private physician was consulted. Morphine was prescribed for the headache, but no relief was obtained.

When seen in the Naval Hospital in the evening of Mar. 7, 1950, the patient gave a history of headache of 36 hours' duration.

*Examination.* He was stuporous but could be aroused. B.P. 126/62, pulse 56, and respirations 16. Temperature 97.8°F. The pupils were pinpoint. The reflexes were hyperactive bilaterally, but no pathological reflexes were obtained. The remainder of the examination was essentially negative. A lumbar puncture at time of admission yielded grossly bloody CSF with an initial pressure of 270 mm. Microscopic examination revealed innumerable RBC. The centrifuged CSF showed the supernatant fluid to be xanthochromic.

On Mar. 8, 1950, lumbar puncture was repeated. The initial pressure was 330 mm. of CSF and again the appearance was bloody. On this day the Oppenheim sign was positive on the left.

The patient was transferred to Kennedy Veterans Administration Hospital on Mar. 14, 1950. The history and findings were as described above, except that the Oppenheim sign could not be elicited.

On Mar. 16, 1950, another lumbar puncture was performed. The initial pressure was 190 mm. of CSF and the fluid was xanthochromic. One week later, a right carotid angiogram was done by the closed method. This was interpreted as being within normal limits. No evidence of aneurysm was noted. On Mar. 29, 1950, a left carotid angiogram was done by the closed method. A vascular anomaly was noted in the left parietal area (Fig. 1). In order to rule out tumor in the area, pneumoencephalography was performed on Apr. 4, 1950. This revealed a filling defect in the anterior horn of the right lateral ventricle (Fig. 2).

* Reviewed in the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions published by the authors are a result of their own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

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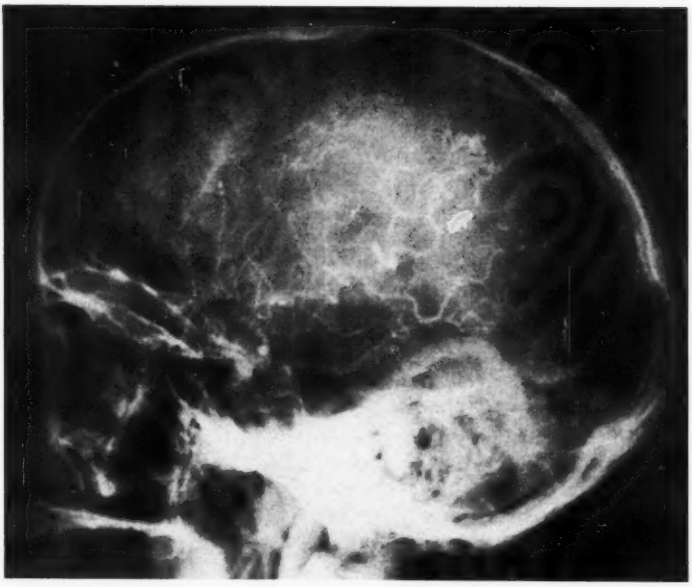

FIG. 1. Angiogram demonstrating vascular plexus in left posterior parietal area.

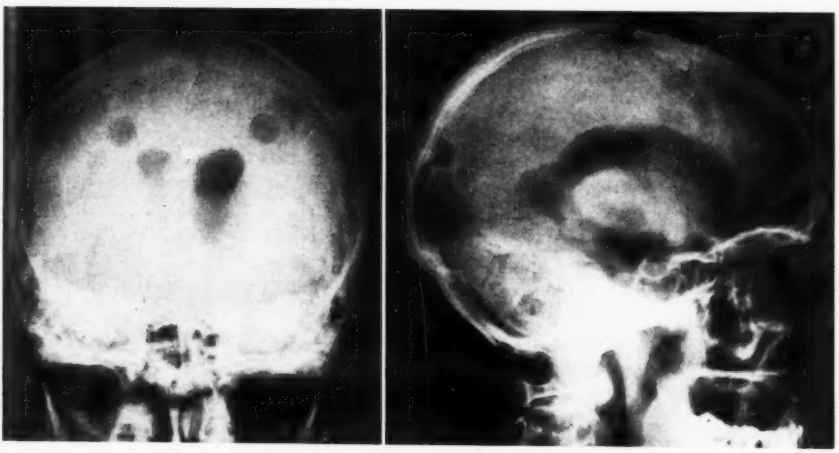

FIG. 2. Showing defect of anterior horn on the right.

*Operation.* After posterior parietal burr holes and a ventriculogram had better delineated the tumor, a right frontal craniotomy was performed on Apr. 12, 1950. The tumor was located in the inferior portion of the right frontal lobe and presumably invaded the corpus callosum. The tumor was partially removed and the tip of the right frontal lobe amputated. Microscopical diagnosis: Astrocytoma, grade III.

*Postoperative Course.* The wound healed per primam and the patient made an uncomplicated recovery. He was given a course of deep x-ray therapy.

Neurological findings on May 23, 1950 were essentially normal. The patient was engaged in normal ward activity prior to his discharge on May 26, 1950. A lumbar puncture on May 22, 1950 revealed an initial pressure of 120 mm. of CSF. This fluid was clear and colorless.

## COMMENT

Our case differs from that of Echols and Rehfeldt in that the symptomatology was of such short duration and angiographic findings suggested an anomaly on the left side. The patient's ictus was precipitated by slight trauma. The history, examination, and laboratory findings are consistent with subarachnoid bleeding, associated with leaking cerebral aneurysm. A cerebral tumor on the right was not suspected. The patient was considered to have an aneurysm since it has been shown that in the majority of cases profuse subarachnoid bleeding is caused by aneurysms.[5,7]

Study of the left carotid angiogram demonstrated a vascular anomaly in the area, but the type of anomaly was not definitely identified. It was thought best to rule out a tumor in this area by air studies. The spinal fluid at this time was clear and colorless and within the normal pressure range. Pneumoencephalography was performed, which revealed the unsuspected right frontal lobe tumor. This tumor surrounded the anterior horn of the right lateral ventricle and is believed to have been responsible for the subarachnoid bleeding because of its location and vascularity. The transient Oppenheim, which was the only pathological reflex obtained, is more consistent with a right-sided lesion. The vascular abnormality on the left was not inspected, although it is realized that this anomaly may have contributed to the subarachnoid bleeding. It is known that intracranial tumors do not always cause an elevated spinal fluid pressure. Furthermore, Adson and Lillie[1] have shown that the intracranial pressure may fluctuate within wide limits in the presence of a known brain tumor. The tumor in our case may have caused sufficient pressure to obstruct the venous flow from the vascular anomaly, even though the spinal fluid pressure was not consistently elevated. The slight trauma added to the presumed increase in venous pressure may have been enough to cause the leakage of blood into the subarachnoid space.

It is suggested from the study of this case that air studies may be indicated in patients with subarachnoid bleeding for which no cause can be found. It is realized that angiography has its limitations and that vascular abnormalities are not invariably detected by this diagnostic procedure. Air studies in patients with subarachnoid bleeding and negative arteriograms might detect neoplasms or hematomas which would otherwise be overlooked.

## SUMMARY

1. A case of profuse subarachnoid bleeding associated with an infiltrating glioma is presented.

2. The glioma may have caused increased venous pressure precipitating bleeding from a vascular anomaly.

3. It is suggested that perhaps air studies should be included as part of the diagnostic study of patients with subarachnoid bleeding in whom an aneurysm cannot be demonstrated.

REFERENCES

1. Adson, A. W., and Lillie, W. I. The relationship of intracranial pressure, choked disc, and intraocular tension. *Trans. Amer. Acad. Ophthal. Oto-laryng.*, 1927, *32:* 138–153.
2. Echols, D. H., and Rehfeldt, F. C. Profuse subarachnoid hemorrhage caused by cerebral glioma. *J. Neurosurg.*, 1950, *7:* 280–282.
3. Globus, J. H., and Sapirstein, M. Massive hemorrhage into brain tumor. Its significance and probable relationship to rapidly fatal termination and antecedent trauma. *J. Amer. med. Ass.*, 1942, *120:* 348–352.
4. Hesser, F. H. Clinical manifestations of glioblastoma multiforme. A review of fifty cases. *N.C. med. J.*, 1948, *9:* 179–186.
5. Magee, C. G. Spontaneous subarachnoid hemorrhage. A review of 150 cases. *Lancet*, 1943, *2:* 497–500.
6. Russel, C. K., and Kershman, J. Spontaneous subarachnoid haemorrhage and brain tumour (a report of 3 cases). *Canad. med. Ass. J.*, 1937, *36:* 568–577.
7. Schwartz, H. G. Subarachnoid hemorrhage and intracranial aneurysm. *Postgrad. Med.*, 1948, *4:* 307–314.
8. Strauss, I., Globus, J. H., and Ginsburg, S. W. Spontaneous subarachnoid hemorrhage. Its relation to aneurysms of cerebral blood vessels. *Arch. Neurol. Psychiat., Chicago*, 1932, *27:* 1080–1130.
9. Wilson, R. B. Multiple gliomas of the brain simulating vascular disease. *J. med. Ass. Ga.*, 1937, *26:* 464–467.

# THE SYNDROME OF BRAIN ABSCESS WITH CONGENITAL CARDIAC DISEASE

## REPORT ON A CASE WITH COMPLETE RECOVERY

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Brain abscess associated with congenital cardiac disease is a very uncommon finding. Wechsler and Kaplan,[7] in a review of the subject, collected 12 cases from the literature and added 2 of their own. They pointed out that in only 1 of the previously reported instances was a diagnosis made during life; all the others were accidental autopsy findings. Reports on the subject have been added by Hanna,[3] and by Vann and Miller.[6] Robbins[4] found 3 cases of brain abscess in a group of 53 patients with fatal congenital cardiac disease. In his comprehensive report (1945) he comments: "Brain abscess is a relatively unrecognized complication of congenital heart disease, . . . so little, that only rarely does one find reference to it in any standard textbook of medicine . . . . In all probability, this apparent obscurity and paucity of reported cases represent the failure either of their recognition or of their publication rather than the rarity of their occurrence." A case in which the diagnosis of abscess of the brain was made and the patient cured surgically was placed on record by Smolik, Blattner and Heys.[5] Among the very recent reports were those of Gates *et al.*[1] and Hand.[2]

The following is a description of a case showing this syndrome.

### REPORT ON A CASE

S. K., a 6½-year-old boy, was admitted on Aug. 16, 1948, because of convulsive seizures of Jacksonian type of 10 days' duration.

Family history was irrelevant except for the fact that the boy's parents were cousins.

Past history was significant in that a diagnosis of congenital cardiac disease had been made at the age of 3 months. The child had been under constant medical care since that time. In his infancy he had suffered from frequent "colds." He had pneumonia twice, at the age of 3 and

at the age of 5. He had measles at 3 and chickenpox at 4. A tonsillectomy had been performed at the age of 4. The boy was known to be unable to stand any physical strain because of easy fatigability and dyspnoea, with subsequent cyanosis.

On August 6, 10 days prior to admission, the boy fell down the stairs while playing. Half an hour later, while talking to his mother, jerking movements began in his right arm and leg, he turned blue in the face, and then lost consciousness. He regained consciousness "after several minutes" but remained paralyzed in the right arm and leg for 3 to 4 hours, after which the paralysis cleared up completely. A second seizure, which followed the same pattern, came on 2 days later, again with complete recovery from paralysis after several hours. During the following week there were repeated episodes of jerking movements in the right arm, which occasionally spread to the right leg, without loss of consciousness. The patient was seized with a third convulsion 2 days prior to admission. This time after regaining consciousness he remained paralyzed in the right extremities, vomited, was very apathetic and refused to eat. According to his mother, he showed difficulty in speaking after the last attack.

*Examination.* The boy appeared acutely ill, and was very irritable and uncooperative. Pulse rate, respiration and temperature were normal. Significant findings were: moderate de-

FIGS. 1 and 2. *Left*, AP view. Displacement of ventricular system to the right.
*Right*, Right lateral view. Compression of left ventricle.

gree of cyanosis, clubbing of the fingers, enlargement of the heart with a thrill and a loud harsh systolic murmur over the entire precordium, most pronounced in the right 3rd intercostal space. The retinal veins were slightly engorged, with normal disc margins. There was right central facial weakness. There was paralysis of the right upper and lower extremities with exaggerated hyperactive tendon reflexes and Babinski sign on the same side. The abdominal reflexes were absent and the cremasteric reflex was diminished on the right side. There seemed to be diminished pinprick appreciation on the right side.

Laboratory findings: Urine: normal. Blood culture: negative. Blood count: RBC 5,200,000; hb. 12 gm.; hematocrit 42; WBC 12,800; neutrophiles 68 per cent, lymphocytes 26 per cent, monocytes 6 per cent. Urea: 24 mg. per cent. Sugar: 104 mg. per cent. Total protein: 5.8 per cent.

X-ray of the skull did not reveal any abnormality.

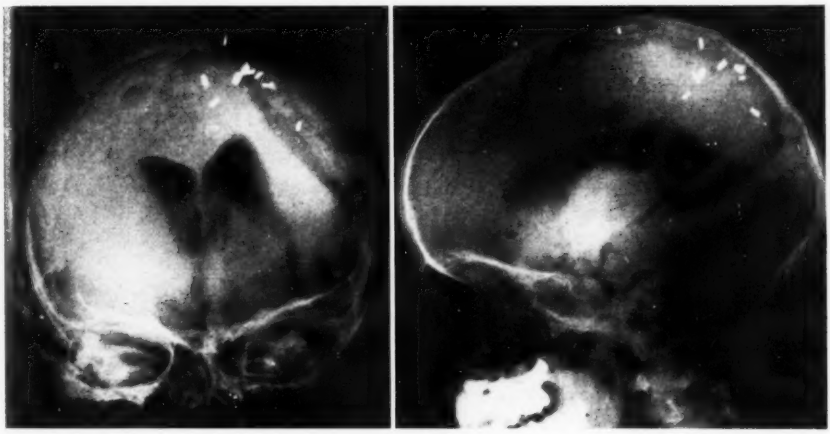
On radiologic examination the heart was sandal-shaped and the apex rounded and elevated. There was a concavity at the pulmonary segment. The hilar markings were increased with transmitted pulsation. The intravenous angiocardiography showed immediate and simultaneous filling of the aorta and the right heart. The left heart was not filled until the seventh second film. The pulmonary artery trunk was not outlined but its branches were

demonstrated. X-ray diagnosis: Tetralogy of Fallot with extreme overriding of the aorta to the right.

Lumbar puncture on August 17 revealed clear CSF under pressure of 120 mm. of water. There were no cells; protein 75 mg. per cent; sugar 84 mg. per cent.

Wassermann and Kahn tests in blood and CSF were negative. Encephalography on August 18 (Figs. 1 and 2) indicated a space-occupying lesion in the left parietal region.

*Operation.* On Aug. 20, 1948, a left frontoparietal skin flap was outlined under local anesthesia. Before the skin-bone flap was turned down, a burr hole was made at its posterior border. The dura was found to be under increased pressure and was then opened. The dural edges and cortex were coagulated and a brain cannula was introduced into the brain substance. At a depth of 2 cm. a resistance was felt and after this was pierced, greyish-brownish pus was obtained. Forty cc. of pus were removed; a smear showed gram-positive cocci. The outlined skin-bone flap was then turned down. The opening in the dura was enlarged and a small flap reflected anteriorly. The cortex was coagulated for a distance of 5 cm. and then incised. This incision was deepened down to the capsule. Blunt dissection of the capsule from



FIGS. 3 and 4. Postoperative pneumoencephalograms. *Left,* AP view. Normal position of ventricular system. Enlargement of posterior part of left ventricle. *Right,* Enlargement of left ventricle in direction of abscess cavity.

the white brain tissue was carried out by means of cottonoids without difficulty, except for its medial wall. This was adherent to the falx and during dissection the capsule was torn and some drops of pus came out. The excised capsule measured $6 \times 3\frac{1}{2} \times 4\frac{1}{2}$ cm. and contained 30 cc. more pus. After careful hemostasis the cavity was filled with saline solution which contained 25,000 units of penicillin and 10,000 of streptomycin. The dura was completely closed, skin-bone flap replaced, and skin closed without drainage.

*Culture* of the material obtained from the abscess revealed hemolytic streptococci.

*Course.* The patient was given 250,000 units of penicillin and 3 gm. of sulfadiazine daily for 14 days. There was a rapid and steady improvement in the first week. The child was out of bed on the 12th day. On the 18th day after operation an infection of the wound at the medial border was noticed. The material discharged from the wound was cultured and showed a growth of Staphylococcus aureus. This was treated locally with penicillin, but showed no tendency to heal. Nine weeks after operation the parasagittal part of the craniotomy wound was reopened, the skin edges and the unhealthy margin of the bone flap were removed, and the wound was closed with skin sutures. There was complete healing after this procedure.

Pneumoencephalography 4 months after operation showed the ventricular system in

normal position with slight enlargement of the posterior part of the left lateral ventricle where the original lesion had been (Figs. 3 and 4).

The patient was last seen in July 1950, almost 2 years after operation. He attends his regular classes and has no complaints whatsoever. Complete neurological examination, including visual fields, did not reveal any abnormal findings.

## COMMENT

The patient was sent in to the children's ward of our hospital by the attending pediatrician with the diagnosis of cerebral embolism due to his heart condition. The history of repeated seizures of Jacksonian type, following the same pattern during 10 days, seemed to indicate a rather well-localized irritating lesion. The differential diagnosis of brain abscess and neoplasm was considered. Air studies performed by the lumbar route established the existence of a well-demarcated space-occupying lesion in the left centroparietal region. There were no clinical or laboratory findings indicating an inflammatory process of the central nervous system. The fact that the patient was known to suffer from congenital cardiac disease and the recent paper on this subject published by Gates *et al.*[1] which called our attention to this syndrome for the first time, made us consider the diagnosis of abscess more probable.

The relationship between the two conditions of the heart and brain is not a coincidence, but a definite syndrome, although little attention has been focused on this subject in literature. The brain complication in a patient with congenital cardiac disease is generally diagnosed as an embolic manifestation. That explains why references to premortem diagnosis and successful surgical intervention are uncommon in the literature.

There was no clinical evidence of bacterial endocarditis or endarteritis in this case nor in others reported. The source of infection in the brain must therefore be sought elsewhere. The generally accepted opinion is that the venous-arterial shunt which is common to all cases of this syndrome explains the mechanism of the suppuration in the brain. "Paradoxic" infected emboli, which normally are filtered by the pulmonary capillaries, can reach the large circulation through the congenital defect and thus get into the brain. The primary focus of infection, which may have any etiologic relation to the brain abscess, does not necessarily show clinical manifestations as it did not in this case.

The most common malformation of the heart in this syndrome is tetralogy of Fallot. In this case the clinical, radiologic and cardio-angiographic findings suggested the same diagnosis.

The surgical management of the abscess in the brain in this case was complete enucleation after the existence of a well-formed capsule was verified by tapping the abscess. This procedure was supported by systemic administration of penicillin and sulfadiazine, which proved sufficient to control the spread of infection in the brain even though some drops of pus fell into the abscess cavity during the surgical manipulations. The local infection of the wound which showed a different organism can hardly be related to the abscess itself. It was resistant to local application of penicillin and healed only after the necrotic bone margins had been removed. The air studies were repeated in this case in order to exclude another abscess in a silent brain area. It should be pointed out that the metastatic abscess encountered in this syndrome is most often solitary. This fact together with the great advances in surgical treatment of brain abscess emphasize the importance of early recognition of this syndrome.

SUMMARY

A case of brain abscess associated with congenital cardiac disease is reported. The relationship of these two conditions is stressed. In each case of cerebral complication in congenital cardiac disease air studies should be performed in order to rule out a space-occupying lesion. In most instances early recognition of the syndrome will permit surgical intervention with cure.

The author is indebted to Dr. S. Schorr of the X-ray Department for his helpful advice.

REFERENCES

1. Gates, E. M., Rogers, H. M., and Edwards, J. E. The syndrome of cerebral abscess and congenital cardiac disease. *Proc. Mayo Clin.*, 1947, *22:* 401–412.
2. Hand, A. Cerebral abscess: a complication of congenital cardiac disease (Fallot's tetralogy). Report of two cases with diagnosis and operation. *J. Pediat.*, 1947, *31:* 662–668.
3. Hanna, R. Cerebral abscess and paradoxic embolism associated with congenital heart disease. Report of seven cases, with a review of the literature. *Amer. J. Dis. Child.*, 1941, *62:* 555–567.
4. Robbins, S. L. Brain abscess associated with congenital heart disease. *Arch. intern. Med.*, 1945, *75:* 279–283.
5. Smolik, E. A., Blattner, R. J., and Heys, F. M. Brain abscess associated with congenital heart disease. Report of a case with complete recovery. *J. Amer. med. Ass.*, 1946, *130:* 145–147.
6. Vann, H. M., and Miller, R. E. A case of pseudo-monoventricular heart terminating in brain abscesses. *Anat. Rec.*, 1944, *88:* 155–160.
7. Wechsler, I. S., and Kaplan, A. Cerebral abscess (paradoxic) accompanying congenital heart disease. Report of two cases. *Arch. intern. Med.*, 1940, *66:* 1282–1289.

## A NEW VENTRICULAR NEEDLE*

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We have devised a new type of ventricular needle (Fig. 1) which we feel has added advantages over the conventional type. The point of the needle is an in-

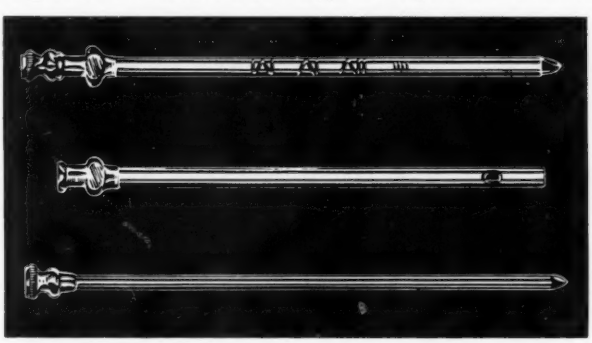

Fig. 1. New ventricular needle with and without stylet.

* Presented at the meeting of the Neurosurgical Society of America, Quebec, P.Q., October 1949

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tegral part of the stylet, so that when the stylet is withdrawn, the bore of the needle is unobstructed. Should it be desired to catheterize the ventricle, a small #8 French rubber catheter may be easily inserted into the ventricle directly through the needle; the needle is then withdrawn, allowing the catheter to remain in the ventricle, thus facilitating ventricular drainage or even the injection of air or oxygen.

If ventricular decompression is decided upon subsequent to ventriculography, the #8 French rubber catheter can be inserted without reopening the wound, merely by reneedling the ventricle.

The needle is made in two different styles, one with multiple perforations along the cannula, the other with a continuous uninterrupted cannula. The latter is of use in making small punch biopsies. The hub of the needle is constructed so that it may be used with a Luer-Lok syringe or a three-way stop-cock.

## NOTICES

### AMERICAN ACADEMY OF NEUROLOGY

The next meeting of the American Academy of Neurology is scheduled for April 11 to 13, 1951, at the Cavalier Hotel, Virginia Beach, Virginia. It will be preceded by a two-day course in neuropathology, and will be followed by the 1951 meeting of the American League Against Epilepsy. Anyone interested in the course in neuropathology may write to Dr. Dave B. Ruskin, 301 Second National Bank Building, Saginaw, Michigan, for details.

### SOUTH AMERICAN CONGRESS OF NEUROSURGERY

The fourth South American Congress of Neurosurgery will be held at Porto Alegre, State of Rio Grande do Sul, Brazil, from May 6 to 12, 1951. Neurosurgeons in the United States and Canada are cordially invited to attend. Inquiries relating to the Congress may be directed to Professor Eliseu Paglioli, Faculty of Medicine of Porto Alegre, State of Rio Grande do Sul.

### SPANISH-PORTUGUESE SOCIETY OF NEUROSURGERY

The fourth meeting of the Spanish-Portuguese Society of Neurosurgery will take place in Madrid from April 26 to 29, 1951 and will be held jointly with the Society of British Neurological Surgeons. Members of the Harvey Cushing Society and other American Societies are cordially invited. Those who are interested may communicate with Mr. William R. Henderson, General Infirmary, Leeds, England or with Dr. S. Obrador, Instituto de Neurocirugia, Olivos 22, Madrid.

WALTER E. DANDY

# WALTER E. DANDY—SURGEON
## 1886–1946

ELDRIDGE CAMPBELL, M.D.*
*Albany, New York*

(Received for publication November 7, 1950)

Thou renderest to every man according to his work.
Psalm LXII, 12.

THE shadow of a great scientist shrinks little with the passage of years. Walter Dandy would have rejoiced in the thought that subsequent generations judged him according to the validity and usefulness of his contributions to surgery. For when measured by this yardstick alone, there is every reason to believe that his shadow, like that of his chief, Professor Halsted, is actually growing longer rather than shorter.

The depiction of a man can be better comprehended when viewed against the background of his early life. Walter Dandy was born in Sedalia, Missouri, on April 6, 1886, the only child of John and Rachel Dandy. The parents had emigrated from Barrow-in-Furness, Lancashire, England, but two years previously. John, a locomotive engineer, was a Socialist and a member of the religious sect known as the Plymouth Brethren. In the son's antipathy toward England, and particularly to her caste system, he was no doubt early influenced by the feelings of his father and mother.

### PREMEDICAL EDUCATION

He attended the public school in Sedalia, from which he was graduated first in his class. On entering the University of Missouri in 1903, he found it necessary to earn most of his expenses. This proved a blessing in disguise, for the laboratory jobs he obtained not only introduced him to scientific investigation, but brought him into contact with W. C. Curtis, the Professor of Zoology. Evidently Curtis appreciated Dandy's talents and encouraged his interests in much the same way that Johnson and Bovell stimulated young Osler. Curtis once took Dandy as his laboratory assistant on a scientific expedition to Muscle Shoals.

On graduation from the University of Missouri, his outstanding character, scholarship and athletic ability were recognized by the offer of a Rhodes Scholarship. By that time he was anxious to begin the study of medicine, and since in that era this was not possible at Oxford, he declined the scholarship. Both parents were much disappointed, for despite the many faults they had found with England, they wanted their son to have an English University education and even to live there. Such was not to be the case, for even then young Walter had a strong mind of his own. That

* Albany Hospital, Albany, New York.

autumn (1907), with the help of Professor Curtis, he was admitted to the Johns Hopkins Medical School.

## MEDICAL SCHOOL

Because of his exceptional work in science as an undergraduate, he was admitted to the second-year class. He was graduated in 1910, standing high in his class. Dr. L. Whittington Gorham, a classmate, relates that in medical school both Dandy's ability and determination were readily apparent; that he was exceedingly hard working, taking little time out for the Saturday night convivialities which are even yet reported to be indigenous to that part of Broadway between Monument and Jefferson Streets.

## GENERAL SURGICAL TRAINING

It was the opinion of Professor Halsted, and strongly shared to the end of their lives by both Cushing and Dandy, that a broad education in general surgery was the most secure foundation on which to build a career in one of its specialized fields. By the time of graduation, young Dandy had attracted the Professor's interest and was selected for training. As was customary, the first year was spent in the Surgical Hunterian, or "Dog House." In addition to investigative work, his duties included the teaching of operative surgery to undergraduates. In 1911 he came on the House Staff, where he served as intern and then assistant resident until 1916, when he was appointed resident. Having held this post for two years, he relinquished it to Dr. Mont Reid and went into practice as a general surgeon.

In order to understand how Dandy's rapidly growing practice soon became entirely neurosurgical, it is necessary at this point to retrace our steps to 1907. Professor Mall had received one of the youngest human embryos up to that time discovered and entrusted its study to young Dandy, then an undergraduate. Mall's confidence was well placed, for in January, 1910, his senior year, he published as his first paper, "A Human Embryo with Seven Pairs of Somites Measuring About 2 mm. in Length." In embryological literature the specimen is still referred to as the "Dandy Embryo." Largely on the basis of this work, he was, in the same year, awarded an M.A. degree by the Johns Hopkins University. It is interesting to note that but two brief paragraphs were devoted to the nervous system, whereas he appeared particularly intrigued by the vascular system, several pages having been devoted to its description. The work was done with scientific thoroughness and in minute detail. The author's enthusiasm is evidenced by such a statement as "finding many beautiful examples of endothelial proliferation . . . . "

In the Surgical Hunterian he came into contact with Dr. Harvey Cushing who, in association with a brilliant group of young surgeons, Drs. George Heuer, Samuel J. Crowe, Emil Goetsch, and John Homans, was investigating pituitary function. At the suggestion of Dr. Cushing, Dandy undertook a study of the blood and nerve supplies of the canine and feline pituitary bodies. In two papers, published in 1911 and 1913, both the origins and

courses of the blood vessels and nerves supplying the various portions of the pituitary complex were clearly described. He observed that the anterior lobe received "about eighteen or twenty small arteries which converge toward the stalk from the various components of the circle of Willis," and that the posterior lobe received its arterial supply from a "small artery formed by the union of a symmetrical branch from each internal carotid." The pars intermedia was discovered to receive its blood supply from vessels of the stalk, from the adjacent brain and from the posterior lobe. He went on to point out that "a collateral circulation therefore exists between the anterior and posterior lobes. . . . " The sympathetic nerve fibres were found to be carried on the walls of the entering arteries. There are two points of additional interest in these papers: One, the beautiful drawings made by the author under the coaching of Max Brödel, and second, his repeated expressions of gratitude to Dr. Cushing for his help.

In conjunction with Leonard Rowntree, Dandy next studied fluid absorption from the abdominal and pleural cavities. Von Recklinghausen's theory of absorption through lymphatic stomata located largely within the central tendon of the diaphragm was still incompletely disproved, and Fowler, on this basis, had instituted the position that still bears his name in the treatment of acute peritonitis. By using phenolsulfonphthalein the two young investigators demonstrated that dye injected into either cavity appeared in the bloodstream within 2–4 minutes, in the urine within 4–6 minutes, but not in the thoracic duct until 20–60 minutes later; within an hour 40–60 per cent had been eliminated by the kidneys, whereas only 1 per cent had appeared in the thoracic duct. Von Recklinghausen's theory had received its death blow.

Carrying their study a step farther they found that fluids were readily absorbed, regardless of the posture of the animal. To their surprise they discovered that the rate was consistently reduced when the pelvis was dependent, thus showing that there was merit in Fowler's position, although for a reason other than that originally supposed.

After the year (1910–11) in the Surgical Hunterian, Dandy became a member of the Surgical House Staff. In that day, general surgery was "Allgemeine Chirurgie," and included neurosurgery. Cushing's pioneer work had already gone far toward establishing the latter as a specialty field and a number of the young members of the House Staff had developed a lasting interest in it. At about that time, two events occurred that were of profound significance in Dandy's subsequent career: First, he had a violent quarrel with Dr. Cushing.* One result of this episode was that Dandy

* What the beginning of this unfortunate disagreement was will probably never be known completely. Dandy himself told Dr. Thomas R. Brown that it had to do with the publication of the hydrocephalus papers (vide infra); another account has it that it began one day when Dandy was assisting Cushing and attempted to do something with his left hand, an effort which drew the soul-searing injunction: "Use your right hand Dandy, you're clumsy enough with that." In retrospect the incident would appear to have been incidental, for the chemical compositions of their respective hypothalamuses was such that propinquity was synonymous with conflict.

believed he had lost his position, and in Dr. Halsted's absence was temporarily granted room and board in the hospital by Dr. Winford Smith. He actually went to Albany to consult with Dr. Arthur Elting about practising surgery there. Eventually, however, the Professor returned, Dandy's reappointment was confirmed and matters were again on an even keel. Halsted's early confidence in the young man was to be amply justified. In the second place, Dr. Cushing left the Johns Hopkins in 1912 to accept the Chair of Surgery at Harvard.

## HYDROCEPHALUS AND THE CIRCULATION OF THE CEREBROSPINAL FLUID

At the age of 27, Dandy (in conjunction with Blackfan) published the first series of ten, now classic papers on hydrocephalus and the circulation of the cerebrospinal fluid. Prior to that time no satisfactory explanation of either had been arrived at. Dandy was able, in the dog, to produce dilatation of the lateral and third ventricles by obstructing the aqueduct of Sylvius, to produce distention of one lateral ventricle by obstructing its foramen of Monro and to prevent the latter by previous removal of its choroid plexus. By separating the Pacchionian granulations from the great venous sinuses both over the vertex and at the base of the dog's brain, he demonstrated that hydrocephalus did not result, and, therefore, that cerebrospinal fluid absorption did not occur in that manner (as was widely believed) but rather, directly into the blood vessels in the subarachnoid spaces.

In the autopsy room an obstruction either at the aqueduct of Sylvius or at the foramina of Luschka and Magendie or along the basilar cisterns was demonstrated in every case of "idiopathic" hydrocephalus. This disorder was thus reclassified, upon a solid basis of anatomical and physiological study and of clinical observation, into communicating and non-communicating types. The operations of choroid plexectomy and third ventriculostomy were logical sequences of these discoveries.

Dandy's reputation had become international. Dr. E. A. Park, a lifelong friend, wrote that not long after this first publication (1913), Professor Halsted, who was exceedingly proud of his pupil, remarked, "Dandy will never do anything equal to this again. Few men make more than one great contribution to medicine." In this instance the Professor's estimate was to prove at fault.

## VENTRICULOGRAPHY

In 1918, while resident surgeon, Dandy made his greatest, and probably the greatest single contribution to neurosurgery, ventriculography. He has said that the idea came to him in one of Professor Halsted's clinics, when attention was drawn to the sharp outlines made by intestinal gas (v.i.). In a way it was an outgrowth of his work on hydrocephalus; the first 20 ventriculographies were performed on infants and children. He commented at the time, however, that the method should lend itself admirably to the diagnosis and localization of tumors in adults. Spinal encephalography was intro-

duced the following year. Today these procedures are indispensable aids in every neurosurgeon's practice.

His critics reacted to the painful impact of this new idea by denouncing ventriculography as both dangerous and unnecessary. Dandy was sure he was right and persisted with the courage and determination that characterized his life work. It was perhaps not unnatural, however, that he should have felt some bitterness towards those particular neurosurgeons and neurologists.

## PNEUMOPERITONEUM

General surgery owes a rarely recognized debt to Walter Dandy. On Jan. 3, 1917, a patient whose abdomen he was about to explore for intestinal perforation chanced to have a chest x-ray taken on the way to the operating room. Dr. Baetjer, who made the picture, included in it the upper abdomen. Air was clearly visible under the diaphragm. Operation confirmed the presence of intraperitoneal air, as well as the perforated typhoid ulcer through which it had escaped. The usefulness of this discovery has been amply confirmed on hundreds of subsequent occasions.

It is of interest that this was the very roentgenogram that originally suggested to Dandy the use of air to outline the cerebral ventricles!

## THE ACOUSTIC NEUROMA

In the early days of neurosurgery, removal of tumors of the cerebellopontine angle carried an appalling mortality. While Ballance had performed a successful removal in 1894, Gordon Holmes commented some 29 years later that he personally had seen but one survivor (a patient of Sir Victor Horsley's) and that he was badly crippled. As late as 1913 Horsley, von Eiselsberg and Krause reported operative mortalities of 67, 77 and 84 per cent respectively. Inadequate exposure, ineffective hemostasis, coupled with an attempt to remove the tumor in toto by means of the finger or a spoon, were obviously causes of failure. Horsley, whom Dandy admired greatly, made neurosurgical hemostasis practicable by his introduction of bonewax, and the use of muscle stamps, but these in themselves were not enough. Decompression alone over acoustic tumors proved harmful rather than beneficial. Krause inaugurated ventricular puncture (which he first performed by trochar through the tentorium), also a most helpful procedure. The first great advance, however, in this problem came with Cushing's monograph on *Tumors of the Nervus Acusticus* (1917) in which adequate exposure of the tumor following bilateral suboccipital craniectomy, removal of the arch of the foramen magnum with release of the herniated cerebellar tonsils, ventricular puncture, the use of silver clips for hemostasis and finally and principally, his method of intracapsular enucleation were described. In his masterful hands the mortality was lowered to circa 10 per cent.

Dandy, when surgical resident, removed his first acoustic neuroma in 1917. This was an in toto extirpation and successful. A second triumph was

followed by 4 successive fatalities and a conviction that a new method must be developed. Cushing's intracapsular enucleation was taken up with "enthusiastic hopes." After early initial success, signs of medullary compression developed in the first patient, requiring re-exploration. No hemorrhage but an oedematous tumor shell was discovered and removed; recovery followed promptly. This and subsequent similar experiences, together with the realization that eventual recurrence was almost inevitable, led him to the development of his now standard operation of total removal. He took pains to state that without the aid of Cushing's silver clips and Cushing's method of preliminary intracapsular enucleation, the procedure would not have been possible.

At a later date, the operation was further modified to include a relatively small unilateral flap and the resection of the lateral "cap" of cerebellum overlying the tumor.

## THE HYPOPHYSIS

The function as well as the surgery of this gland intrigued Dandy throughout his life. In association with Reichert he studied the effects of its extirpation on the growth of puppies, and later investigated gland removal, stalk stimulation, and destructive lesions of the infundibular region in relation to diabetes insipidus. Growth of puppies was found to cease or be greatly retarded, as had been shown before by Aschner. They commented on the inconstancy of their and other investigators' results in producing polyuria and polydypsia. It could only be concluded that "there appears to be a neurogenic mechanism which can be set off by mechanical and thermal stimulation of the base of the brain and of the hypophysis as well, but that the hypophysis is not an indispensable part of it . . . . It is our belief that only the human experiments will solve this problem."

Four years later Dandy was to report the significant case of a girl whose hypophysial stalk had been clearly severed, and who, for the next 11 years, had had diabetes insipidus. Anterior pituitary function, as judged by two normal pregnancies, normal lactation, menstruation, weight, skin, hair, etc., had remained unimpaired.

The intracranial attack on pituitary tumors was probably inaugurated by Krause in Berlin. This was modified by Frazier and later by Cushing. The approach was extradural, the dura being finally divided at the sphenoidal wing. The frontal sinus was usually traversed.

The intradural approach was devised by Heuer,* who immediately preceded Dandy as resident surgeon. This procedure entailed a large frontoparietal bone flap. Dandy subsequently modified it by using a small frontal flap with concealed skin incision and by lowering the vertex of the head as soon as the dura was opened in order to obtain better exposure with less

* In Dr. Heuer's absence overseas during the First World War, the operation was actually published for him, at his own and Professor Halsted's requests, by Dr. Dandy. This was done, of course, to establish priority.

retraction of the frontal lobe. The frontal sinus could be readily avoided. This operation has now been widely adopted.

## THE PINEAL

In no phase of neurosurgery did Dandy display more perseverance and ingenuity than in the evolution of his operation for removal of pineal tumors. In 1911 he undertook the study of the effects of pinealectomy on dogs. Long and painstaking dissections of the veins of Galen followed by excision of the gland yielded not one survivor. Later he began to work through the roof of the third ventricle and to dissect the gland out more accurately, but still no more than a quarter of the animals survived. He kept on and two years later discovered an approach that yielded a high percentage of successes. The posterior 2 cm. of the corpus callosum were divided in the midline, the "anaemic area" in the roof of the third ventricle between the small veins of Galen was entered and the pineal, then clearly visible, removed with cupped forceps. Instead of the 3 or 4 hours required for earlier procedures, the last consumed less than one and was accompanied by little bleeding.

A series of young puppies was prepared in this way. Subsequent study of the group disclosed "no sexual precocity or indolence, no adiposity or emaciation, no somatic or mental precocity or retardation," and hence that the pineal was not essential to life or well being.

Here was concrete evidence of physiological importance.

The application of knowledge gained in the laboratory to problems in the clinic was ever Dandy's obvious objective. In 1921, he described an adaptation of the canine pinealectomy operation to man and recorded 3 cases. One of these patients had a tuberculoma and survived 8 months, only to die of a recurrence of the disease elsewhere. Even by 1936 he was able to record but 3 temporarily successful cases. Some men might have been discouraged by these results—there is no evidence that Dandy was. He remained to the end aggressively interested in improving the operative results in cases of pineal tumors. In 1945 he recorded the removal of 20 such growths with an operative mortality of 5; one patient was alive and well 6 years after operation, another $4\frac{1}{2}$ and others for shorter periods.

## PNEUMOCEPHALUS

Since the publication of Chiari's famous case in 1884 it had been known that under certain conditions air might enter the cranial cavity spontaneously. With the subsequent advent of roentgenography these cases were recognized more frequently. Many of the patients died as the result of increased pressure or from meningitis. Frazier and Grant early realized that dural closure was indicated to forestall infection. In a well documented and reasoned paper published in 1926, Dandy gave a comprehensive portrayal of the pathological and clinical findings in this condition. Of even greater importance, he established for the first time, by the included case reports,

the fact that closure of the dural opening was not only highly desirable but readily feasible.

## TIC DOULOUREUX

Probably no phase of Dandy's work better exemplified his originality, his contempt for established surgical custom, or his brilliance as an operator than his papers on trigeminal neuralgia. For a number of years he had been unhappy over the facial palsies, the corneal ulcers, and hemiplegias which occasionally followed the classical operation of Krause and Frazier. The unavoidable battle with the middle meningeal artery and the venous sinuses before the days of electrocautery, suction and Frazier's method of operating with the patient sitting up, made another method of attack desirable. His attention was directed to the accessibility of the sensory root at the pons as seen following complete removal of an acoustic neuroma.

Discoveries come most readily to the mind prepared. A woman presented herself for relief of pain from a carcinoma of the antrum. The tumor, in which there was a low-grade infection, had extended backwards to involve the temporal fossa. The safest approach to the trigeminal nerve was through the posterior fossa. The operation proved successful and the feasibility of this avenue of approach was established.

During the next 20 years Dandy performed well over 500 partial or total divisions of the sensory root by this method with less than 1 per cent mortality. He believed the advantages of subtotal section at the pons to be that: Corneal ulceration did not occur; the motor branch was never paralyzed; there was little disturbance in facial sensation; facial paralysis rarely occurred; and hemiplegia was always avoided. In later years he said that approximately 10 per cent of patients with subtotal divisions of the sensory root would, in time, have recurrence of tic pain; in the younger group, therefore, he came to perform total divisions.

A heated controversy followed concerning the safety of the Dandy operation as well as over the claims made concerning its advantages. Certainly in Dandy's hands the complications and mortality were minimal; tempers were not soothed when it was stated that the procedure should be attempted only by *expert* neurosurgeons! Another *cause célèbre* was the statement that the fibres carrying tic pain from all three divisions lay in the posterior half of the sensory root. The experience of Frazier and others with partial division performed but a few millimetres further from the pons led them to quite opposite conclusions. The fact that at least 90 per cent of tic patients were permanently cured by partial division of the sensory root at the pons lent strong credence to Dandy's theory. On the other hand, an anomalous location of this bundle of fibres would have to be assumed for the 10 per cent whose tic pain recurred. The points remain unsettled today.

Glossopharyngeal tic douloureux was but gradually differentiated from the trigeminal variety, as was brought out by the excellent paper of T. H. Weisenburg in 1910 and later by J. B. Doyle (1923). The following year

(1924) Adson reported his experiences with peripheral neurectomy,* and because of recurrence of symptoms in one case, advocated intracranial division of the ninth nerve. In 1926 Fay sectioned the ninth nerve intracranially, along with the upper three cervical nerves, for pain caused by malignant disease.

It remained for Dandy, in 1927, to record the first two cases of intracranial division of the glossopharyngeal nerve for tic. He strongly advocated this rather than peripheral neurectomy because of the greater ease and safety and also because of the permanence of the cure.

It was but a simple step to combine his operations for fifth and ninth nerve division (as had individually been reported by Grant, 1926, and by Fay, 1926), with or without upper cervical nerve division, for malignancies of the face, mouth, and throat (1929). This procedure has proved a blessing to many a patient suffering from one of these intolerably painful lesions.

## MÉNIÈRE'S DISEASE

Twenty-six years before the turn of the century, the great Charcot made the observation that attacks of aural vertigo ceased when deafness became complete in the affected ear. He lamented that eighth nerve division was not then surgically feasible. Actually, Frazier, in 1912, had divided the auditory nerve for "persistent aural vertigo" and again for "persistent tinnitus," the latter only being followed by considerable improvement. The matter was apparently allowed to drop there until Dandy, in 1924, with his then considerable familiarity with the cerebellopontine angle, took up the operation. By 1928 he was able to report 9 operations, all successful. The value as well as the safety of the operation was firmly established. The efficacy of section of the vestibular portion alone, first suggested by Dandy and established independently by McKenzie, was amply corroborated. Patients in such numbers sought relief that by 1943 he recorded 564 operations; there was but one death. It is hard to see how this record will ever be surpassed!

## INTRAVENTRICULAR TUMORS

In 1933 and 1934 Dandy published his classic monographs on tumors of the third and of the lateral ventricles. The clinical pictures were drawn upon the basis of his singularly large personal experience. The ventriculographic findings were clearly demonstrated and served in good measure to explain the development of signs and symptoms. The high recovery rate reflected not only the precision of his diagnostic methods but his superb operative skill.

Probably in no other phase of brain tumor surgery has ventriculography been more valuable. What wonder then, that the late Professor W. W. Keen asked why Dandy had not been awarded the Nobel prize for this great discovery.

* This operation was first reported by Sicard and Robineau in 1920.

## INTRACRANIAL ANEURYSMS

Dandy was fascinated by any kind of vascular anomaly of the brain. Whenever an abnormal collection of veins or arteries was exposed in the cortex, he would stop and examine it in every accessible detail, usually sending for the artist, Mrs. Padget, and all the while wondering aloud what he might do to correct it. On those occasions he appeared oblivious to the passage of time, a situation otherwise rarely observed in his operating room. In his numerous explorations in cases of Jacksonian epilepsy many vascular abnormalities were encountered. A splendid discussion of their roles in convulsions, along with a series of beautiful drawings of the lesions by Mrs. Padget, are to be found in his article on "Venous Abnormalities and Angiomas of the Brain" (1928). In the same year he recorded 8 cases of congenital arteriovenous aneurysm, all of which were disclosed at operation. In one patient the ligation of the arterial trunk was followed by collapse of the mass of veins and subsequent improvement; an attempted resection of a second resulted in fatal hemorrhage; all of the remainder survived. Although twenty years later Pilcher and Olivecrona were able to record a number of successful excisions, Dandy's bold pioneering, for the most part sans electrocautery, sans continuous suction, sans blood bank, and sans peur, commands one's admiration.

Dandy first isolated a carotid-cavernous fistula in 1934 (published the following year). It proved not only a valuable adjunct to the treatment of the lesions by carotid ligation in the neck but as an introduction to his great work on berry aneurysms of the circle of Willis.

March 23, 1937 marked another milestone in neurosurgery, for on that date Dandy first cured an aneurysm of the intracranial carotid by clipping its neck. The principle of isolation of the lesion as previously worked out for the carotid-cavernous fistulae, was carried over to this problem: in the discussion of the procedure he states that he believed before the operation that the aneurysm arose from the posterior communicating artery and that "it was hoped that a silver clip could be placed upon the artery on each side of the aneurysm if there was not a satisfactory neck by which the aneurysm could be attacked directly." In his classic monograph "Intracranial Arterial Aneurysms" (1944) he was able to record the cure of 20 out of 36 such lesions exposed at operation. Never favorably impressed by the capricious results of carotid ligation in the neck alone, he believed, as the result of his own and the early experiences of German, of Cone, of Fincher, and of Woodhall, that the best hope for the patient lay in direct attack upon the lesion by clipping its neck or in "trapping" when circumstances permitted. Deliberate packing of the sac with muscle, as first done by Cushing, and by Jefferson, and later by McConnell, was considered a rational procedure under certain conditions.

He spent much time and effort in studying the neurological pictures of aneurysms in various parts of the circle of Willis; angiography was considered unnecessary to the surgical exposure of many of the lesions amenable

to surgery. He was very wary about injecting diodrast or thorotrast into the carotid; in occasional instances subsequent experience indicates that his apprehension was not altogether unjustified.

## NEUROPHYSIOLOGICAL OBSERVATIONS

It has sometimes been lamented that neither Cushing nor Dandy were previously trained as physiologists. Doubtless this would have saved each a few errors of interpretation. It is hard to believe, however, that two men could have done more for neurosurgery than was managed in their respective threescore-and-ten and threescore years. Naturally their approach was principally from the clinical side, but there are many advantages in studying the human animal.

Several examples might be cited, the *transmission of taste* being a good one. Prior to 1930 at least four different routes from the chorda tympani to the nucleas solitarius had been postulated. That year in a paper written with Dean Lewis it was clearly shown: first, that patients whose glossopharyngeal or trigeminal (sensory root) nerves were divided at the brain stem did not permanently lose the sense of taste on the anterior two thirds of the tongue; second, that permanent loss of taste in this area inevitably followed division of the seventh nerve anywhere proximal to the geniculate ganglion; and third, that intracranial division of the glossopharyngeal nerve was followed by loss of taste only on the posterior third of the tongue. Thus the old theory of Lussana was firmly established.

In the same year (1930) Dandy presented before the American Physiological Society his observations "on the localization of certain functions in the brain." He recorded the first removal in man of the right cerebral hemisphere—minus the basal ganglia—with "No appreciable disturbance in mentality"; a bilateral frontal lobectomy with similar results, "The patient is perfectly oriented as to time, place, and person. The memory is unimpaired; he reads, writes and conducts mathematical feats accurately; his conversation is seemingly normal." Again he found that excision of the left occipital lobe or even the left temporal lobe was not followed by loss of intelligence. It was stated that "The entire body of the corpus callosum may be split in the midline without any appreciable disturbance of function." He concluded that the intellect was "doubtless concerned with the remaining portion of the left cerebral hemisphere and is doubtless closely related to the speech mechanism."

While subsequent study has shown that some of these statements are in need of qualification, this should not serve to detract from the value of these pioneering observations nor from the homage due the observer.

## HEAD INJURY

Two constantly repeated admonitions of Dandy to his house officers were "You must study each patient carefully" and "The less you do to a patient the better." Nowhere were these tenets more evident than in his

regimen for cranial trauma. Doubtless he is best known for his frequent and bitter condemnation of the use of lumbar puncture; actually this was but part of the plan. He advocated rest, an airway kept open by proper positioning of the patient and frequent suctioning, fluids up to 1500 or 2500 cc. per day rather than dehydration, and avoidance of hypertonic solutions, of early roentgenography and, of course, of spinal tapping. Only the mildest sedatives were employed. If the patient were losing ground, exploratory burr holes were made in search of a hematoma and if none were found and the brain were swollen, subtemporal decompression was often carried out.

How did Dandy come to suspect that lumbar puncture was a dangerous procedure in head injuries? That question was once asked him by a junior house officer. In the early 1920's he was called by the late Dr. Richard Follis to see a patient who had suffered a severe concussion. The man had been holding his own for some hours and appeared to be stabilizing satisfactorily when a spinal puncture was performed. Within a few minutes the respiration had become irregular and within an hour had ceased entirely.

Some years later the same sceptical house officer had occasion vividly to recall the above story when a similar tragedy befell one of his own patients!

## RUPTURED INTERVERTEBRAL DISKS

In 1929, Dandy described two cases of "Loose Cartilage from the Intervertebral Disk Simulating Tumor of the Spinal Cord." It so happened that both protrusions were massive and occurred at the third lumbar disk level. The clinical picture was that of a cauda equina tumor, the preoperative impression in each case having been metastatic malignancy. Transdural operation revealed that the mass of cartilage arose from the disk and histological study confirmed the impression that the fragments were not neoplastic. He believed that the "detachment" of those pieces and their bulging into the spinal canal were attributable to trauma, which might have been "slight or repeated," and was probably similar to osteochondritis dissecans. The muscle spasm and vertebral spine tenderness were plainly recorded.

It is of particular interest that he clearly pointed out that "The early symptoms are those of localized vertebral pain *plus bilateral sciatica—one side being affected more than the other.* Later the symptoms are of rapidly increasing paralysis, sensory and motor paralysis and loss of urinary and vesical control and of reflexes—all due to compression of the cauda equina." And finally: "*This lesion offers a pathological basis for cases of so-called sciatica*, especially bilateral sciatica. The lesion is cured by operative removal of the cartilage." (Author's italics.)

Here the matter stood, however, until after the now classic paper of Mixter and Barr, which so clearly depicted the common form of small, laterally placed disk herniations with cervical and lumbar root compression symptoms. At that time, Dandy was evidently unaware of the papers of Goldthwaite or Middleton and Teacher, although he was no doubt familiar

with reports of extradural "chondromas" described by Elsberg, by Mixter, and by Stookey.

At this point, a comment by Professor E. A. Park is of particular interest: "He seemed to the writer suddenly to be seized with intuitions; then, almost as if possessed, he would plunge forward with impetuous energy and boldness toward his goal. Another characteristic was his complete skepticism in regard to all accepted ideas."

At first he appeared doubtful that the syndrome of the small lateral disk could be as common as it was soon being reported. It was twelve years before his next communication on this subject appeared, but by then he had become, as a result of his own experience, an enthusiastic convert. He was greatly impressed by the high degree of accuracy of preoperative diagnosis, particularly as recorded by Mixter and Barr, by Semmes, by Love and by Spurling. He urged that myelography be abandoned in this connection as unnecessary and probably harmful.

Considerable controversy arose when he described a variety of herniation which he termed "The Concealed Disk." This was said to be characterized by "a very tiny bulge of the intervertebral space, with thickening of the spinal ligament; it indents with pressure—gives a sense of fluctuation—. In every case the emerging root has been quite adherent to it."

His last paper on the subject appeared fifteen months before his death and was concerned with the relation of multiple disk protrusions to the symptomatology of spondylolisthesis. He was strongly convinced that the pain was due to multiple herniation, concealed or otherwise, of disks both above or at the site of the dislocation and that their removal was essential for cure. Fibrous or osseous fusion was believed to follow these procedures, rendering spinal fusion unnecessary. Undoubtedly there is much evidence in favor of this rather startling thesis, and its subsequent assay by time and experience is eagerly awaited.

## TRANSCRANIAL REMOVAL OF ORBITAL TUMORS

In 1922 Dandy recorded two cases of optic nerve tumor ("psammomas") which had extended into the cranial cavity, both of which had been exposed by craniotomy. At that time he proposed the transcranial approach to orbital tumors, because of the fact that both parts of the tumor could be removed with greater ease and safety. Twenty years later, in a splendid monograph, he reported 24 orbital tumors, 19 of which had intracranial extensions. There had been but one operative death. There can be no doubt that this operative attack represents a valuable contribution to ophthalmology as well as to neurosurgery.

## LOCATION OF CONSCIOUSNESS CENTER

It was generally believed by his residents that Dandy had the memory of an elephant for clinical and pathological pictures;* an unusual feature of a case might lead to a short but instructive discussion or, on the contrary, to

* As well as for their own particular misdeeds!

a long pensive silence. The prolonged postoperative unconsciousness of a certain patient precipitated ill-omened rumblings, followed by long periods of quiet. That the latter period was spent in hard reasoning became evident to the house officer at a later date.

An obese woman was admitted from a nearby psychiatric hospital with a bilateral frontal glioma. Resection of the one frontal lobe was followed by uneventful improvement. Three weeks later the other frontal lobe was resected; although she lived 17 days, consciousness was never regained. Dandy assumed that the bilateral ligation of the anterior cerebral arteries was responsible, and since the right had been ligated many times without ill effect it was concluded that the center of consciousness was irritated by the left.

When Poppen subsequently reported ligation of this vessel on several occasions without mishap and when Dandy himself had confirmed the correctness of the observation, he freely admitted his error. However, in the same remarkable paper in which he recorded a total of ten instances of prolonged antemortem unconsciousness, he was to demonstrate (with the aid of Mrs. Padget) softening in the anterior portion of (right) corpus striatum (in the three cases in which the basal ganglia were carefully studied). In the other patients there was presumable evidence that this area had been damaged. He believed that necrosis of either the right or the left corpus striatum would result in permanent unconsciousness.

While further observations on this subject are yet needed before its final solution has been reached, it is readily apparent that Dandy's searching inquisitiveness has blazed another highly significant trail.

## VARIA

To discuss in detail all of the contributions of Dr. Dandy would far exceed the present allotment of space.* His papers on the treatment of brain abscess by tapping, on the use of air in the diagnosis of spinal cord tumors, on cysts of the septum pellucidum and cavum vergae, on spasmodic torticollis, on intermittent exophthalmos, on experimental epilepsy, on an operation for scaphycephaly, on resection of the longitudinal sinus and particularly on ligation of the internal carotid represent valuable additions to surgical knowledge. Many of us today would be proud to have written even a few of them.

In the foregoing, undeservedly brief, sketch, emphasis was placed entirely upon Dandy's contributions to surgery. While his operative skill, his courage, and his personality were extraordinary, it is not because of them alone that he ranks as one of the great masters. It is because of his fundamental contributions to surgery that future generations of neurosurgeons will be beholden to Walter Dandy.

The author wishes to express his gratitude to Mrs. Dandy and to Professor E. A. Park for their generous help in the preparation of this paper.

* It is expected that Dr. Dandy's collected reprints will be published in the near future.

# ACUTE SUBDURAL HAEMATOMA

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THE main purpose of this paper is to urge a more optimistic approach to the problem of acute subdural haematoma and to point out a modification of the usual operation for this condition. This modified approach is based on a somewhat different opinion from that commonly held regarding the origin of the haemorrhage.

For many years it has been stressed that extradural haematoma represents an extreme operative emergency, but little has been said regarding the acute subdural haematoma. Too often the impression has been given that those patients with acute subdural haemorrhage always have associated brain damage (contusion, laceration, etc.) of such severity that the situation is hopeless. Authority after authority remarks on the uselessness of searching for the origin of the haemorrhage. A certain number of these patients have little or no brain damage other than that secondary to compression by clot and present a picture in the accident room indistinguishable both in clinical signs and also in the rapidity of downhill progression from extradural haemorrhage. With *immediate* action and in some cases with a modified operative approach many of these patients can be salvaged.

This surgeon feels very strongly that any patient seen in the emergency ward following head trauma who shows definite progression in his neurological picture and deepening of his state of unconsciousness merits exploratory burr holes *immediately*. It is not felt that normal pulse rate or blood pressure or respiratory rate should influence one in determining to let the patient "ride along." Patients may die with an operable intracranial haematoma with a pulse rate in the normal range up to within a few moments of exitus. Bilateral neurological signs, dilated fixed pupils, or tonic fits should not deter one from operative intervention if there has been definite progression in the picture. If a patient is not seen until an hour or several hours following trauma, it is not safe to assume that the picture is due to intrinsic brain damage, but on the contrary intracranial haematoma must be ruled out. The responsibility falls squarely on the shoulders of the surgeon—and too many patients with head injuries still die who might have been saved.

The papers on the subject usually ascribe the origin of acute subdural haematomas to laceration of the veins crossing to the longitudinal sinus. One author has the following to say: "Acute subdural hematomas usually result from extensive laceration of the veins crossing to the sinus [? longitudinal]. As it is impossible to learn which of these many veins is involved it is impossible to control them and surgical treatment of this condition is

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rarely successful."[3] Rowbotham[7] mentions as points of origin of the bleeding: lacerated dural venous sinus, cortical vein with associated tearing of arachnoid, or, most commonly, short communicative veins draining the cortical vessels into the sinuses. His figures show tearing of veins to longitudinal sinus. Browder reported that in 75 per cent of his cases there was a laceration or contusion of the brain implicating the cortical vessels.[1] He mentions that there is a fairly constant vein at the anterior aspect of the Sylvian fissure crossing the subdural space where it joins the sphenoparietal venous sinus which is frequently a source of bleeding. He makes a point, which should be emphasized, that at autopsy it is difficult to impossible to definitely identify the origin of the clot. There is a tendency to talk of the blood trickling to the most dependent parts of the subdural sac and accumulating over and under the temporal lobes, whereas it has been my experience in cases of massive acute subdural haematoma that the blood has welled *up from the base* at operation *rather than originating at the vertex.* This discussion is not concerned with thin layers of blood a few mm. in thickness but only with clots large enough to cause signs and symptoms by compression. In the latter type of case the bleeding is more often than not from the *inferior cerebral veins* running from the inferior surface of the temporal and occipital lobes to the transverse sinus (vein of Labbé, etc.), sphenoparietal sinus, and superior petrosal sinus (middle cerebral vein). These veins may be lacerated or even torn from the sinus with severe rapid bleeding.

The treatment usually recommended, with a suggestion of hopelessness, consists of a subtemporal decompression approach (with no mention made of locating bleeding points), evacuation of clot, and drainage of the subdural space (40 per cent mortality rate).[2,4,5,6,8] Dott, Alexander and Ascroft[2] advocate treatment by "evacuation of clot and arrest of bleeding if still in progress." Aspiration of the haematoma and drainage of the cavity is also advocated with the admonition that no attempt be made to find the bleeding point, the sealing of which is left to natural processes. Other writers condemn the use of a wide osteoplastic flap or a wide subtemporal decompression with the comment that in an acute head injury the simpler the operation the greater the chances of recovery. The bleeding points that are left to nature unfortunately have a habit of bleeding more profusely than ever with the clot removed. Drainage of the subdural space, unless the "clot" is almost pure cerebrospinal fluid, is highly ineffective—if it were effective many of the patients would be exsanguinated on the table. One would not turn one's back on severe venous or dural sinus bleeding at the time of tumor removal and I see no reason to do so in traumatic cases. In many instances, at least, the search for the bleeding point or points will be successful and fewer cases will come to autopsy with findings such as the following—"R died of a *ruptured pial emissary* vein on the left side of the head which caused a *subdural haematoma.* There were no lacerations of the brain of any sort." No surgical exploration was carried out on this patient although he lived for hours following trauma.

A brief mention of the anatomy of the inferior cerebral veins follows: The inferior cerebral veins drain the lower part of the external surface of the hemisphere. There are two main groups—the lateral occipital and middle cerebral. The lateral occipital veins are formed by small trunks from the inferior and lateral surfaces of the occipital lobe and more important channels from the posterior part of the temporal lobe, the main one passing down from the posterior extremity of the lateral fissure (vein of Labbé). The veins may be single or multiple and usually empty into the middle portion of the transverse sinus after a short course in the tentorium cerebelli. The middle cerebral vein draining the anterior exterior surface of the frontal lobe and the anterior portion of the temporal lobe may curve backward on the under surface of the temporal lobe to end in the superior petrosal sinus, or may commonly pass over to the dura at the lesser sphenoid wing to continue as a sinus across the depths of the temporal fossa, entering the superior petrosal sinus after anastomosing in transit with the middle meningeal veins. It may also empty into the cavernous sinus directly or via the sphenoparietal sinus. A petro-squamous sinus is sometimes present, lying in a small groove at the junction of the petrous and squamous portions of the temporal bone and opening behind into the lateral sinus.

## OPERATIVE PROCEDURE

The operative approach used by the author permits direct access to the commonly involved vessels.

The patient's head is completely shaved. After the scalp is cleaned up the usual oblique incision is marked out, extending upward from the zygoma anterior to the ear slightly backward to a point just below the insertion of the temporal muscle. A small incision, about 2.5 cm. long, is made at the upper part of this scratch through muscle to bone and exploratory burr holes are made. If extradural clot is encountered it is evacuated, and the bleeding points are stopped through the classical subtemporal decompression approach. If, on the other hand, the dura is opened and massive subdural clot is encountered and there is persistent bleeding, every effort is made to locate the source of haemorrhage. If the blood wells up from the base, as is often the case, a curved incision is carried posteriorly above and behind the ear and, depending on the patient's condition and the rapidity of blood loss, either a small bone flap can be turned down hinged on the temporal muscle (Case 2) or, if speed seems essential, the muscle is stripped downward from the bone and the bony defect is rapidly enlarged with the rongeurs (Case 1).

In either case the bony defect is carried down to the base and the dura is opened widely, permitting easy accessibility to the inferior cerebral veins draining into the transverse sinus with minimal if any retraction of the brain.

Bleeding from veins or sinuses can be stopped by cautery, gelfoam or muscle. The dura is left open to permit postoperative decompression. The muscle is closed over the bony defect. No cranioplasty has been considered necessary at a later date in these cases.

Two cases are reported to illustrate the use of this more posterior approach. The first case was handled through rongeuring away the bone to provide the approach. A bone flap was turned down in the second case, in which speed seemed less important.

## CASE REPORTS

*Case 1.* L. G., 32-year-old white male, was admitted to the accident room Dec. 11, 1949, approximately 30 minutes after an automobile accident. At this time he was deeply unconscious with marked spasticity throughout and a fully dilated fixed left pupil. There were multiple lacerations and abrasions of the scalp with a large haematoma over the left occipitoparietal region. B.P. was 115/110 on admission at 2:45 A.M. At 3:00 A.M., when first seen by the author, B.P. had risen to 190/110; P. was 56, and R. 24. Both pupils were now dilated and fixed, and the patient was having rapidly recurring tonic fits. Although the situation appeared hopeless it was felt that there had been definite evidence of progression and the patient was taken immediately to the operating floor, a portable skull film being taken while the operating team scrubbed. The film showed a linear fracture extending toward the base in the left parietal region.

*Operation.* The procedure was carried out without even local anaesthesia being necessary, so deep was the patient's state of unconsciousness. A U-shaped skin flap was turned down behind the ear on the left side, with the anterior limb of the flap extending just forward of the ear so as to permit extension downward with the routine subtemporal decompression incision if necessary. On retracting the skin flap a linear fracture could be made out in the underlying bone. A perforator opening was made in the bone and enlarged with the burr. There was no extradural blood but the dura was very tight and bluish in appearance. A burr opening was then made in the left frontal region about 3 cm. from the midline and slightly above the hairline. The dura was incised in the frontal region and a large quantity of semisolid blood clot extruded under tremendous pressure. Attention was then directed to the posterior bony defect, which was enlarged with the rongeurs after the temporal muscle was stripped downward from the bone. The bony opening extended downward to the base of the skull, uncovering the posterior temporal and anterior occipital lobes. The dura was opened widely in a stellate manner, revealing a tremendous amount of clot, measuring about 4 cm. in depth, overlying the entire left hemisphere. This was removed with the use of suction, saline and the gloved finger. There was active venous bleeding from the base with the blood welling up in a continuous stream. It seemed unlikely that the bleeding points could be controlled but after temporarily stopping the flow of blood with cotton packs it was found that the entire haemorrhage was from the veins bridging from the posterior aspect of the left temporal lobe and anterior aspect of the occipital lobe to the transverse sinus. The torn veins were cauterized and the sinus bleeding was controlled by cotton packs and finally by gelfoam and thrombin solution. It should be stressed that there was no thick clot of blood in the floor of the middle fossa but the blood had ascended from the region of the transverse sinus up over the convexity of the hemisphere. The brain re-expanded to some extent and could be seen to pulsate normally. The exposed cortex looked perfectly normal. Gelfoam was placed over the exposed cortex and the temporal muscle resutured. The bony defect measured approximately $7\frac{1}{2} \times 4$ cm. Galea and skin were then closed with interrupted sutures. An exploratory burr hole was made over the right temporal lobe. There was no extradural or subdural blood on this side and the

cortex appeared normal. The right lateral ventricle was tapped, a few cc. of practically clear fluid being obtained. Patient still did not respond to stimuli immediately following operation but his blood pressure had dropped to normal levels and his pupils reacted to light.

*Course.* Within 6 to 8 hours the patient began to respond to painful stimuli and he continued to improve quite rapidly. Within 48 hours a left 3rd nerve paralysis developed without pupillary involvement and this began to clear within the first few weeks. The right-sided signs were entirely gone within 48 hours but there was a marked left hemiplegia with spasticity, positive Babinski and ankle clonus. It was felt that this hemiplegia, ipsilateral to the clot, was the result of pressure of the right cerebral peduncle against the free edge of the tentorium. After a period of 6 months there was present a *minimal* left hemiparesis. The left 3rd nerve palsy had entirely cleared. The patient's mental state was normal. There was no aphasia. The patient was left-handed.

*Case 2.* C. B., a 50-year-old white male was admitted to the accident room Oct. 29, 1947, following an automobile accident, unconscious without any localizing neurological signs. He regained consciousness within a few minutes of the time that he was seen but was somewhat disoriented. During the next day he became progressively more confused and aphasic (mainly sensory), and complained of severe headache. There was no change in B.P., pulse rate or respiratory rate. The patient was right-handed.

*Operation.* A U-shaped skin flap was turned down in the left temporo-occipital region behind the ear. A small bone flap was then turned down, hinged on temporal muscle. The dura was tense and bluish in color. On opening the dura a large amount of semisolid blood clot was evacuated. The brain was depressed perhaps 3 to 4 cm. away from the dura. After removal of the clot there was active bleeding from the veins bridging to the transverse sinus. This bleeding was controlled by cotton packs, cautery and finally gelfoam. An intracerebral haematoma, about the size of a golf ball, was evacuated from the posterior inferior part of the temporal lobe. The dura was resutured, the bone flap replaced and galea and skin were closed in layers with interrupted black silk sutures.

*Course.* This man had an uneventful postoperative course with complete clearing of his aphasia. In the following several years he has had occasional right-sided seizures.

## SUMMARY

This paper points out the not infrequent occurrence of massive bleeding from the inferior cerebral veins and dural sinuses in acute subdural haematoma and stresses a more vigorous attempt to find the actual bleeding points and seal them off. A more posterior operative approach is outlined which permits rapid accessibility to the vessels that have often been involved in the author's experience. Two cases exemplifying these points are presented in some detail.

## REFERENCES

1. Browder, J. A resumé of the principal diagnostic features of subdural hematoma. *Bull. N. Y. Acad. Med.*, 1943, *19:* 168–176.
2. Dott, N., Alexander, G. L., and Ascroft, P. B. Injuries of the brain and skull. In: *Surgery of modern warfare.* H. Bailey, Ed. Edinburgh: E. & S. Livingstone, 1944, 3rd ed., 717–759

3. Grinker, R. R., and Bucy, P. C. Neurology. *Springfield, Ill.: Charles C Thomas*, 1949, 4th ed., ix 1138 pp. (see p. 830).
4. Kennedy, F., and Wortis, H. "Acute" subdural hematoma and acute epidural hemorrhage. A study of seventy-two cases of hematoma and seventeen cases of hemorrhage. *Surg. Gynec. Obstet.* 1936, *63:* 732–742.
5. Munro, D. Cerebral subdural hematomas. A study of three hundred and ten verified cases. *New Engl. J. Med.*, 1942, *227:* 87–95.
6. Peet, M. M. Extradural hematoma, subdural hematoma, subdural hydroma. In: *Injuries of the skull, brain and spinal cord. Neuro-psychiatric, surgical, and medico-legal aspects.* S. Brock, Ed. Baltimore, Williams & Wilkins Co., 1943, 2nd ed., ix, 616 pp. (see p. 125).
7. Rowbotham, G. F. Acute injuries of the head. Their diagnosis, treatment, complications and sequels. *Baltimore: Williams & Wilkins Co.*, 1945, 2nd ed., xvi, 424 pp. (see pp. 66, 80, 142).
8. Spurling, R. G. Craniocerebral trauma. In: *Surgical treatment of the nervous system.* F. W. Bancroft and C. Pilcher, Ed. Philadelphia: J. B. Lippincott Co., 1946, 27–62 (see pp. 56–57).

# NOTES ON THE COLLATERAL CEREBRAL CIRCULATION AS DEMONSTRATED BY CAROTID ANGIOGRAPHY

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When Moniz in 1926 introduced cerebral angiography as a new diagnostic method, it was a contribution of no less value than the cerebral pneumography introduced by Dandy 8 years previously. For the detection of intracranial disorders, and especially for the diagnosis of intracranial neoplasms, these two radiological methods are indispensable to the neurosurgeons of today.

For the full appreciation of carotid angiography, and for the understanding of its diagnostic possibilities and limitations, a fundamental knowledge concerning the carotid circulation under normal and pathological conditions is necessary. A few remarks referring to this point may therefore be appropriate.

While a contrast medium injected into the carotid artery of a corpse readily proceeds to the contralateral hemisphere, as shown by Moniz,[5] this is normally not so in a living person. Under normal circumstances the blood stream through the internal carotid artery on each side proceeds to the homolateral hemisphere, and, if at all, only to a slight degree intermingles with the blood flow from the internal carotid artery on the opposite side.

Partial or total obliteration of the internal carotid artery on one side, with consequent partial or total circulatory arrest, demands a compensatory supply of arterial blood from the patent internal carotid artery in order to prevent symptoms due to cerebral anaemia.

In cases of insufficiency of the communicating arteries many neurosurgeons have seen the development of disastrous clinical conditions, such as hemiplegia or even death, following ligation of the internal carotid artery. Valuable prognostic information in cases of contemplated ligation of the internal carotid artery may be obtained by carotid angiography, which readily discloses to what extent one hemisphere may be supplied by arterial blood from the carotid on the opposite side.

We shall attempt to demonstrate the collateral circulation which is called into activity in cases of obliteration of the internal carotid artery (1) at its beginning near the bifurcation of the common carotid artery; (2) at the point where the internal carotid artery bifurcates into the anterior and middle cerebral arteries; and (3) in cases of hypoplasia of the internal carotid artery. Possible secondary collaterals which may develop in cases of long-standing obliteration of the internal carotid artery will also be discussed.

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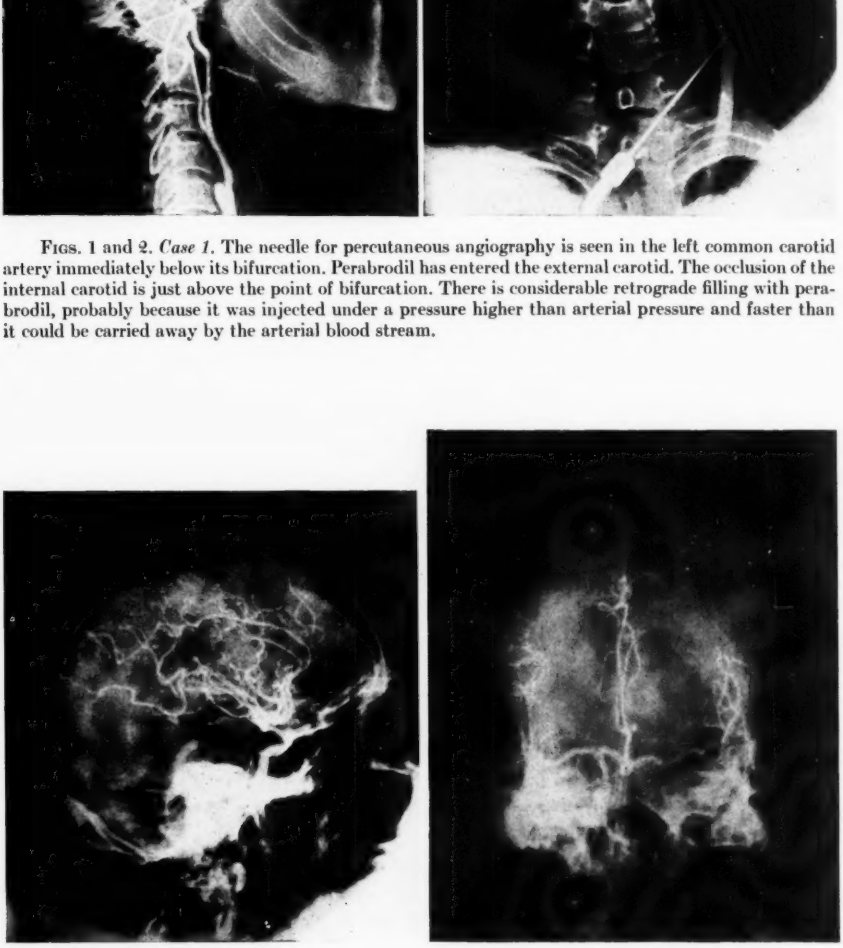
FIGS. 1 and 2. *Case 1.* The needle for percutaneous angiography is seen in the left common carotid artery immediately below its bifurcation. Perabrodil has entered the external carotid. The occlusion of the internal carotid is just above the point of bifurcation. There is considerable retrograde filling with perabrodil, probably because it was injected under a pressure higher than arterial pressure and faster than it could be carried away by the arterial blood stream.



FIGS. 3 and 4. *Case 1.* Right carotid angiography. There is satisfactory filling with perabrodil of the branches of both anterior and middle cerebral vessels. The AP view shows that these vessels on the left side are supplied by blood also from the right internal carotid.

All the angiograms shown in this paper were carried out by the percutaneous technique.[9]

## CASE REPORTS

The first case was one of spontaneous obliteration of the internal carotid artery immediately above the bifurcation of the common carotid artery.

*Case 1.* Marcus M., a 46-year-old man, was admitted on Oct. 10, 1948. On July 27, 1948 he had noticed some motor dysphasia, and about 2 weeks later he experienced a gradual onset of hemiplegia on the right side which developed to such an extent that he finally could move neither arm nor leg. Later some improvement took place.

Angiography disclosed a complete occlusion of the internal carotid artery closely above the carotid bifurcation (Figs. 1 and 2). The perabrodil entered the external carotid artery but no contrast medium was seen in the internal carotid above the occlusion. The contrast was evident in the common carotid nearly down to its very beginning, probably because it was injected more rapidly than the external carotid could take in.

In order to study the intracranial circulation, carotid angiography was also done on the right side (Figs. 3 and 4). The contrast may be seen in the hemispherical vessels on both the right and left sides, where branches of the anterior and the middle cerebral arteries are easily distinguishable.

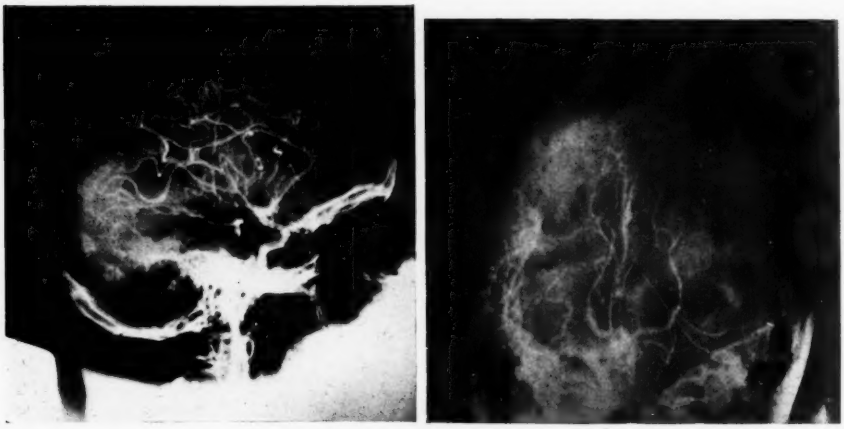
FIG. 5. *Case 1.* Injection of contrast medium into right carotid artery with simultaneous digital compression of left carotid artery.

Normally the intracranial vessels on the side opposite to the injection are seen only after compression of the internal carotid artery on that side, and the filling is usually definitely less than on the injected side. This, however, varies with the technique of the compression and in successful cases the angiograms may be almost equally satisfactory (Fig. 5). The bilateral filling takes place by way of the communicating arteries and is no cause for surprise.[7,8]

It is of greater interest to note that the contrast medium not only passes over to the opposite side but also descends into the internal carotid on the opposite side, which apparently means a movement of the contrast medium contrary to the normal blood stream. The explanation for this is probably the fact that the comparatively large ophthalmic artery draws a considerable amount of blood, and if the physiological flush of arterial blood to this artery by way of the internal carotid is impeded or interrupted, a corre-

sponding amount of arterial blood bound for the orbit is drawn from above by the alteration of the intravascular pressure.

Such apparently reversed progression of arterial blood containing the contrast medium may also take place in other arteries. Thus in one case we have seen arterial blood containing perabrodil descend into the basilar artery (Figs. 6 and 7). This case is our sole example of bilateral filling with contrast of the posterior cerebral artery by carotid angiography in a material of about 2,800 cases and may deserve to be mentioned separately:



FIGS. 6 and 7. *Case 2.* Right carotid angiography resulted in bilateral filling of posterior cerebral arteries with perabrodil. There is retrograde filling of the basilar artery.

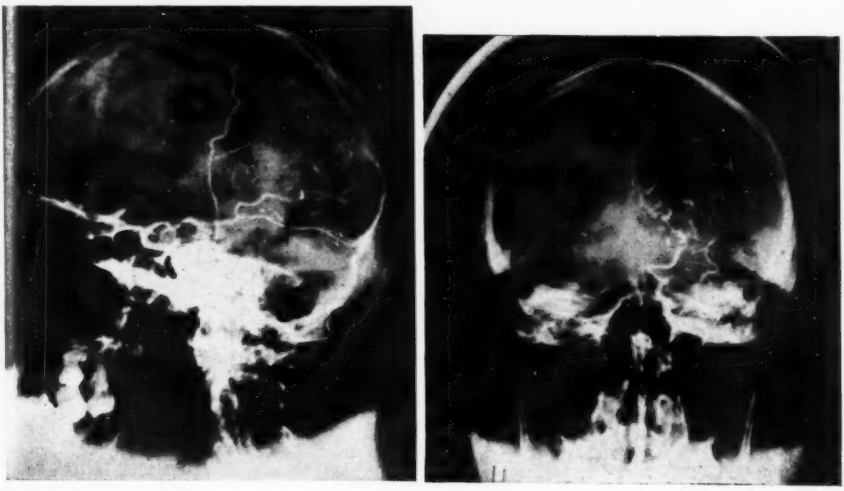
*Case 2.* Ruth S., a woman aged 18 years, was admitted on Feb. 3, 1949. For about 4 months she had suffered from generalized headaches and occasional spells during which she said that she could not move the limbs although she did not lose consciousness. She was in an apparently semicomatose state, and carotid angiography was carried out on the right side. The findings were indefinite, but a possible deviation of the anterior cere-

FIG. 8. *Case 2.* While bilateral filling of the posterior cerebral arteries was seen after injection of perabrodil into the right carotid artery, no similar finding was observed after injection into the left carotid.

bral artery to the right was observed (Fig. 7). The outstanding finding was a bilateral filling with perabrodil of both posterior cerebral arteries. There was also filling of the uppermost portion of the basilar artery. The arterial blood containing the contrast medium had descended into the basilar artery for a few cm. contrary to the normal blood stream. No similar finding was obtained by angiography on the left side, which was done a few days later (Fig. 8).

The patient displayed many features suggesting a psychogenic basis for her illness. She was discharged somewhat improved, no certain diagnosis having been made. Her condition had not changed noticeably 1 year later.

The establishment of a collateral circulation in cases of occlusion of the



FIGS. 9 and 10. *Case 3.* Left carotid angiography resulted in filling of the external carotid with contrast medium. The internal carotid has also been filled nearly to its division into anterior and middle cerebral arteries. These vessels, however, could not be visualized by carotid injection on the left side, while the left posterior cerebral artery was easily demonstrated.

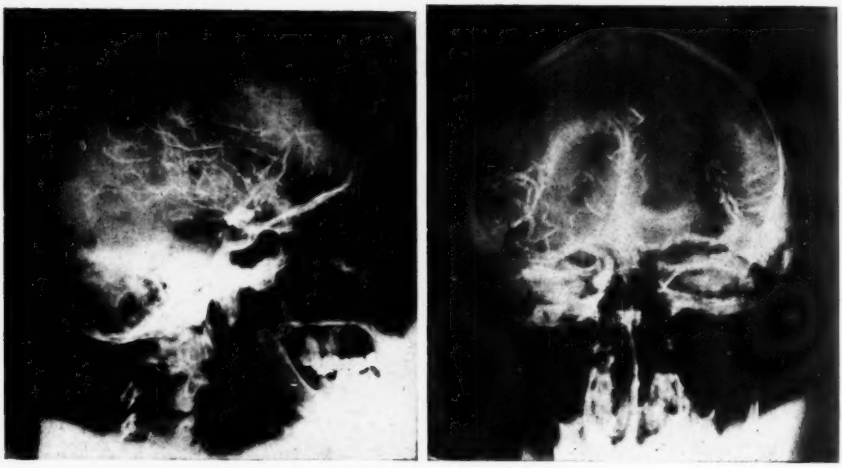
internal carotid artery may take place spontaneously even if a considerable part of the arterial supply is intact. For instance, if the blood flow through the middle cerebral artery becomes disconnected from the homolateral internal carotid artery, it seems more expedient for nature to utilize the contralateral carotid system than to develop a collateral system derived from the posterior cerebral artery within the hemisphere that is in need for arterial blood. The following case demonstrates this point.

*Case 3.* Irma C., a woman 38 years old, was seen in consultation because of continuous headaches. This trouble was dated back to 1938 when she had suffered a head injury followed by unconsciousness for about 1 hour. The headache was predominantly left-sided, was exaggerated by mental or physical strain, and was occasionally associated with paraesthesia of the right arm and leg.

Angiography was performed on the left side (Figs. 9 and 10). The external and

internal carotid arteries were well filled with the contrast medium. However, the anterior or the middle cerebral artery on the left could not be visualized, although the posterior cerebral artery was well filled. The internal carotid artery could be seen all the way from the point where it branches from the common carotid and nearly up to, but not including, the point of its division into the anterior and the middle cerebral branches.

It was suspected that there was an occlusion of the internal carotid artery or its branches at some point above the origin of the posterior cerebral artery. In order to verify this diagnosis, if possible, carotid angiography was performed on the right side. There was bilateral filling with the contrast medium of both the anterior and the middle cerebral arteries (Figs. 11 and 12). Thus, while no blood could enter



FIGS. 11 and 12. *Case 3.* Right carotid angiography. The right anterior and middle cerebral arteries have been filled with the contrast medium. The AP view shows also that spontaneous transgression of blood from the right to the left side has taken place.

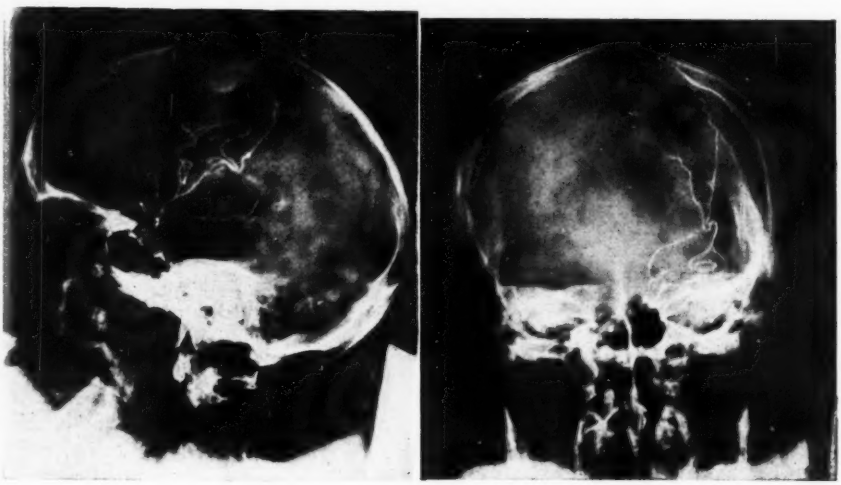
the left anterior and middle cerebral arteries by way of the left internal carotid artery, blood entered these vessels easily by way of the internal carotid on the opposite side. Although the middle and anterior cerebral arteries on the left side were normal in size and shape, no arterial blood was seen to enter these vessels by anastomoses of the posterior cerebral artery.

The angiographic examination proved that the pathological lesion is localized in the internal carotid artery at a point above the origin of the posterior cerebral artery but below the division of the internal carotid into the anterior and the middle cerebral branches.

The examples related above show that in cases of occlusion of the channels conveying arterial blood to the cerebral hemispheres, no matter at which point the occlusion has taken place, if possible a collateral circulation by way of the circulus Willisii is called into activity in order to take over

the function of the diseased vessels. We shall not venture to discuss whether it takes place on a mechanical base caused by the differences in intravascular pressure, as pointed out by Moniz,[6] or if it is due to autonomic reflexes secondary to metabolic changes caused by the ischaemic cerebral condition, as maintained by Krieg.[4]

Apparently the aid of a collateral intracranial circulation is demanded not only in cases of obliteration of the internal carotid artery, but in all cases of decreased arterial blood supply to the hemisphere, independent of its cause. For instance, in cases of early occluding vascular disease or in the presence of hypoplasia of the carotid artery, the arterial blood from the in-



FIGS. 13 and 14. *Case 4.* Angiography performed on the left side shows that the internal carotid is unusually narrow. The branches of the middle cerebral artery are also of smaller dimensions than seen in most cases.

ternal carotid on the opposite side takes part in the hemispherical circulation, as illustrated by the following case.

*Case 4.* Agnes T., a woman 49 years old, was admitted on Dec. 12, 1949. In 1945 she had had a traumatic fracture of the T12 vertebra, followed by discomforts of the legs. The actual cause for admission was epileptic fits of a generalized pattern for the last 4 years. Occasionally the fits were followed by weakness of the right arm and leg.

Carotid angiography was first performed on the left side (Figs. 13 and 14). The outstanding findings were: hypoplasia of the left internal carotid artery; the middle cerebral artery was narrow and its branches were few and of small size; and finally there was no visible anterior cerebral artery.

Carotid angiography was next done on the right side (Fig. 15). The internal carotid artery was of normal size and configuration. The most interesting finding was that both right and left cerebral hemispheres were supplied by blood from the

right internal carotid, this observation being in contradistinction to the finding after injection of perabrodil into the left internal carotid. The left anterior cerebral artery, which was not visible at all on the angiograms after injection of perabrodil into the left internal carotid, was readily filled with the contrast together with the right anterior cerebral artery by the injection of perabrodil into the right internal carotid.

A considerable number of pictures were taken, giving an opportunity to compare the sizes of the right and left internal carotid arteries. The caliber of the artery on the pathological side was definitely (about 30 per cent) smaller than on the healthy side.

## COMMENT

The cases described above illustrate the collateral circulation that is called into activity when there is partial or complete obstruction of one internal carotid artery. These cases have been reported in detail by Koppang,[3] whose publication deals primarily with the possibilities of a collateral circulation.

FIG. 15. *Case 4.* The arteriogram discloses that the left cerebral hemisphere is partially supplied with arterial blood from the right internal carotid.

The arteriograms show that in such cases blood from the internal carotid artery on the healthy side not only proceeds to the pathological hemisphere by means of the circulus of Willisii, but blood containing the contrast medium may also descend into the internal carotid artery on the pathological side for a longer or shorter distance. Such distribution of the contrast may take place, for instance, in cases of hypoplasia of the internal carotid artery, under which circumstance it must be presumed that there remains a considerable blood flow through the artery in spite of its diminished diameter.

It is difficult to understand how a reversed blood stream could be created just for the moment of the injection of the contrast medium, and it must be assumed that in such cases there is a constant blood flow in caudal direction through the carotid syphon. A possible explanation is that the ophthalmic artery draws a quantity of blood that is larger than the decreased capacity of the internal carotid artery on the diseased side can afford, and that a correspondingly additional volume under such circumstances is mobilised from above.

In cases of bilateral occlusion of the internal carotid arteries, arterial blood may reach the cerebral hemispheres by means of the basilar artery.

That life under such circumstances can be continued with comparatively few symptoms has been shown by an example published from this clinic by Frövig.[1]

In discussing the sources from which arterial blood may reach the cerebral hemispheres, the interesting question of the possible participation of the external carotid artery presents itself. In this connection there should be recalled the existence of preformed anastomoses between the external and the internal carotid arteries, mainly by three ways: (1) Branches from the external maxillary artery are connected with branches of the ophthalmic artery by way of the angular artery. (2) Branches from the ophthalmic artery form connections with branches of the temporal artery by way of the supraorbital artery. (3) Intracranial arterial branches of the middle meningeal artery form anastomoses with branches from both the lachrymal and the nasociliary arteries, which again arise from the ophthalmic artery.

The arteries mentioned above are small vessels of probably limited importance in normal cases. It is doubtful if these arterial branches can take over the blood supply to the brain in more than a negligible way in cases of sudden occlusion of the internal carotid artery. In cases of gradual occlusion it may be a different proposition, and it is possible that these anastomoses by gradual enlargement may become of practical importance, especially in cases of long standing. A case suggesting such possibility has been observed in the neurological department. The details of this case are being prepared for publication by A. Frövig, but a brief summary may be given here to illustrate the practical consequences these anastomoses may possibly have for the collateral intracranial circulation:

The patient was a 58-year-old man with a right hemiplegia. Angiography was carried out on the left side. The shadows of the internal carotid artery were evident for only a few mm. above the bifurcation. The external carotid artery was completely visible and of normal appearance. The picture that under normal circumstances would be regarded as a phlebogram (that is, exposure after 4 seconds), showed that there was filling with the contrast both of the carotid syphon and of the middle cerebral artery in the Sylvian fissure. The carotid bifurcation was exposed by operation (Dr. Frövig) and a piece of the internal carotid artery was excised, showing complete obliteration.

The cases depicted above illustrate different forms of occlusion of the internal carotid artery. Such cases have previously been frequently misinterpreted as cases of cerebral thrombosis. From our angiographic experiences we have learned that in cases of gradual or sudden development of hemiplegia the diagnosis of carotid thrombosis should be suspected and angiography, with such possibilities in mind, should not be omitted from the diagnostic procedures.

## REFERENCES

1. Frövig, A. G. Bilateral obliteration of the common carotid artery. Thromboangiitis obliterans? A contribution to the clinical study of obliteration of the carotids and to the elucidation of the cerebral vascular circulation. *Acta psychiat., Kbh.*, 1946, suppl. 39, 79 pp.

2. HULTQUIST, G. T. Über Thrombose und Embolie der Arteria carotis und hierbei vorkommende Gehirnveränderungen. Pathologisch-anatomische Studie. *Jena: G. Fischer*, 1942, 399 pp.
3. KOPPANG, K. Carotis interna-trombose påvist ved perkutan angiografi. *Nord. med.*, 1950, *43:* 82.
4. KRIEG, W. Kollateralkreislaufentwicklung bei Durchblutungsstörungen des Gehirns im arteriographischen Bild. Eine pathogenetische Betrachtung. *Zbl. Chir.*, 1939, *66:* 562–578; 681–699.
5. MONIZ, E. Die cerebrale Arteriographie und Phlebographie. *Berlin: J. Springer*, 1940, viii, 413 pp.
6. MONIZ, E. Trombosis y otras obstrucciones de las carótidas. *Manuales de medicina práctica.* Barcelona-Buenos Aires: Salvat, 1941, 173 pp. (see pp. 49–54).
7. MONIZ, E. Trombosis da carotida interna de etiologia traumatica. *Mem. Acad. Cienc. Lisboa. Classe de Ciencias*, 1948, *5*.
8. SORGO, W. Über den Art. carotis interna-Verschluss bei jüngeren Personen. *Z. ges. Neurol. Psychiat.*, 1939, *167:* 581–585.
9. TORKILDSEN, A. Carotid angiography with special reference to the diagnosis of cerebral gliomas. *Acta psychiat., Kbh.*, 1949, suppl. 55, 168 pp.

# TRACER STUDIES WITH RADIOACTIVE PHOSPHORUS ($P^{32}$)

## ON THE ABSORPTION OF CEREBROSPINAL FLUID AND THE PROBLEM OF HYDROCEPHALUS*

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ALTHOUGH information concerning the processes involved in the absorption of cerebrospinal fluid has gradually been accumulated by a vast amount of experimental work in the past 50 years, a final solution to this problem is as yet not available. Early investigators believed that the cerebrospinal fluid was absorbed into the lymphatic system. With the work of Key and Retzius,[8] the venous system was considered to be the primary pathway of absorption, the actual site being the pacchionian granulations along the major dural sinuses. Lending support to this concept was Weed's description of the arachnoid villi present in all mammalian animals.[12] Detailed examination of the arachnoid villi followed and the most commonly accepted theories as to the absorptive mechanisms of the cerebrospinal fluid have accorded these structures a major role.[2,11,13,14] Other investigators have produced evidence suggesting that the greater portion, if not all, of the cerebrospinal fluid is absorbed into the vascular system, either via the capillary bed of the cerebrum by way of the perivascular spaces,[10] or directly into the small veins of the pia arachnoid over the surface of the hemispheres.[3] Alternative routes of absorption that have been suggested are the choroid plexus[5] and the ependymal lining of the ventricles.[4] Recently Griffith, Fry and McGuinness[4] have revived the concept that absorption occurs into the lymphatic system via the perineural spaces. It is likely that absorption can take place along any of the routes mentioned, but the best available evidence indicates that the cerebrospinal fluid is probably ultimately absorbed into the major venous sinuses. The exact site at which the fluid gains entrance into the vascular system, however, remains in dispute.

The following studies were undertaken to elucidate this question further, and in addition the methods of study have been applied to the problem of hydrocephalus as it exists clinically.

### METHOD

The study was first carried out in dogs. A craniotomy was performed exposing the superior longitudinal sinus. Further exposure of either the cerebral cortex or the cisterna magna was carried out, depending upon whether the tracer was to be injected into the ventricle or the cisterna magna.

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The dura was not opened. A tracer dose of radioactive phosphorus ($P^{32}$*) was then injected into either a lateral ventricle or the cisterna magna. Samples of blood taken from the superior longitudinal sinus at regular intervals were analyzed for the degree of activity. In 2 animals a partial block of the aqueduct was produced after the method of Ingraham *et al.*[6] and the study subsequently repeated.

Similar studies were then extended to two groups of human subjects: (1) Patients undergoing a prefrontal lobotomy, whose absorptive processes were presumably normal, and (2) patients with progressive hydrocephalus of both the obstructive and communicating type. In all of the human experiments the tracer was injected into a lateral ventricle. In addition to sampling the uptake into the superior longitudinal sinus, the activity of femoral arterial blood was likewise studied. The rate of disappearance of the $P^{32}$ from the ventricular system was followed by periodic sampling of the ventricular fluid. An indirect means of measuring the amount of absorption of the cerebrospinal fluid was afforded by quantitative determination of the urinary excretion of the $P^{32}$ for the first 24 hours after injection. All of the subjects studied had normal kidney function as determined by examination of the urine as well as by kidney function tests.

In several of the patients studied at the time of lobotomy, samples of blood were obtained simultaneously through two burr holes, one placed anteriorly and one posteriorly over the superior longitudinal sinus, for comparison of the uptake of $P^{32}$ at these two sites. In 5 subjects the anterior burr hole was placed just posterior to a point where one or more communicating veins from the surface of the cortex entered a pacchionian granulation. These vessels were ligated during the process of sampling superior longitudinal sinus blood, and the effect of such ligation upon the uptake was studied.

Samples for counting were prepared by the method of Jones *et al.*[7] The blood was heparinized and 1 cc. aliquots used. The total 24-hour urine was tested in 1 cc. aliquots, and the ventricular fluid in aliquots of 0.1 cc. diluted 1 to 100. The error from self-absorption was kept below 1 per cent. The samples were counted by the wrap-around technic on a Victoreen Thyrode with an aluminum window of 30 mg./cm$^2$. All counts were corrected for decay to the time of injection.

## RESULTS

### A. *Dogs*

In the control group (Fig. 1) the uptake of $P^{32}$ when plotted against time shows rather inconstant curves with a peak of activity occurring from 5 minutes to as late as 30 minutes after the injection. The degree of activity obtained in the superior longitudinal sinus apparently depends upon the dosage of $P^{32}$ injected, but there is no apparent relation to the site of injection. In 2 animals (No. 2 and No. 5) the study was repeated after the production of a partial block of the aqueduct of Sylvius. In comparison to the controls, it may be seen that with the same dose a lower level of activity

* Injected as $NaHPO_4$ made isotonic with normal saline.

i obtained in the superior longitudinal sinus, although in general the shape of the curve is the same.

Bakay and Lindberg[1] obtained essentially similar results in rabbits. After introducing $P^{32}$ into the cisterna magna, they found the maximum activity of the blood draining the brain to occur at 10 minutes, with a rapid decrease subsequently.

### B. *Human Studies—Lobotomy*

There is less variability in the uptake curves in human subjects than in dogs, the maximum level obtained in the blood usually occurring at about

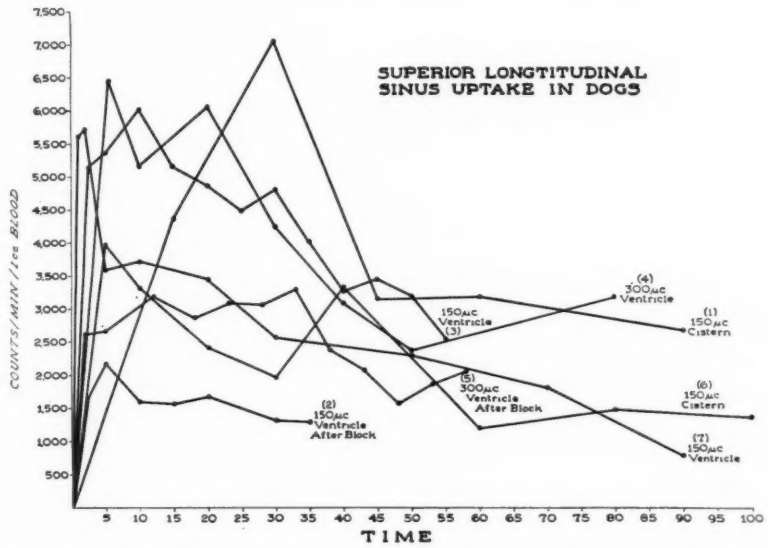


FIG. 1. Curve (3) and curve (2) represent the same animal, as do (4) and (5), before and after the establishment of an aqueductal block.

20 minutes following injection (Fig. 2). The effect of ligation of the communicating veins upon the uptake of $P^{32}$ into the sinus immediately adjacent to the veins is shown in Fig. 3. There was an immediate drop in the activity of the blood obtained from the sinus at this point following the ligation of the veins, whereas samples obtained simultaneously from the sinus farther posteriorly (patients D. V., B. F., C. K.) showed no alteration from the normal curve. It is suggested that the reason for the immediate drop in the activity in the sinus adjacent to the ligation is that the absorption of the $P^{32}$ occurs distal to the pacchionian granulations. The unaltered curve obtained from the posterior portion of the sinus is presumably accounted for by the uninterrupted absorption posteriorly where the communicating veins are intact. The data suggest, therefore, that the passage of the tracer into the

vascular system does not take place through the arachnoidal villi and pacchionian granulations, but rather distal to this point and presumably by a process of diffusion directly into the blood stream by way of the veins or capillaries of the pia arachnoid or cerebral tissue.

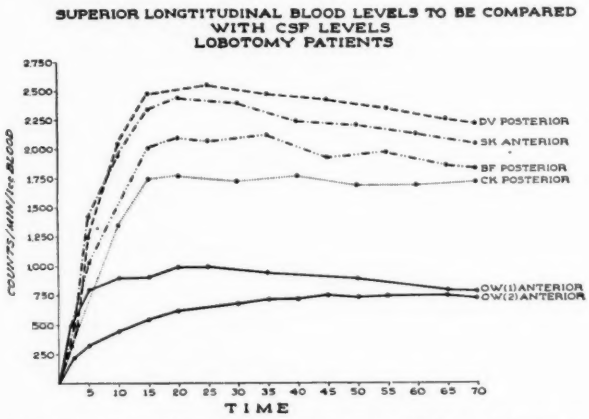


FIG. 2. The captions "anterior" and "posterior" indicate from which burr hole the sample was taken. (Patient O. W. had a communicating hydrocephalus; see Figs. 6 and 7).

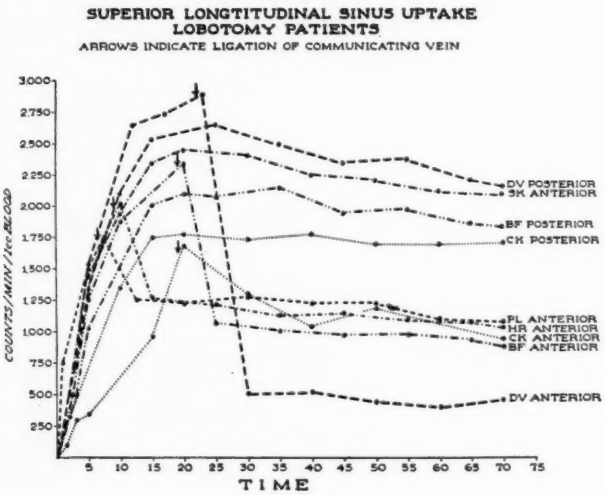


FIG. 3.

The activity of the superior longitudinal sinus blood has been compared with that of arterial blood obtained simultaneously from the femoral artery (Fig. 4). It may be seen that after 40 minutes from the time of injection the arterial activity very closely approximates that in the superior longitudinal

sinus. This suggests that after this interval of time equilibrium is established between the vascular system and the cerebrospinal fluid and that a diffusion gradient no longer exists. However, in the 2 instances in which the com-

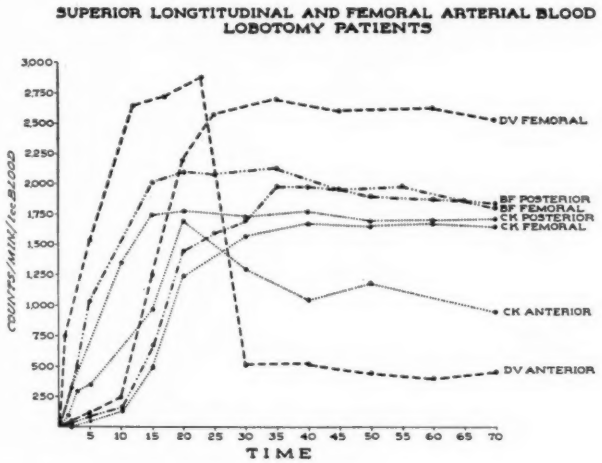


FIG. 4.

municating veins were ligated (C. K. and D. V.) the arterial levels exceed those obtained from the longitudinal sinus at the point of ligation. This finding suggests that the tracer that is being brought back to the brain via the arterial blood re-enters the cerebrospinal fluid and/or the cerebral tissue but still cannot pass into the longitudinal sinus because of the continued obstruction afforded by the ligation.

The rate of disappearance of the tracer from the ventricular fluid is shown in Fig. 5. The rather marked differences in the ventricular fluid

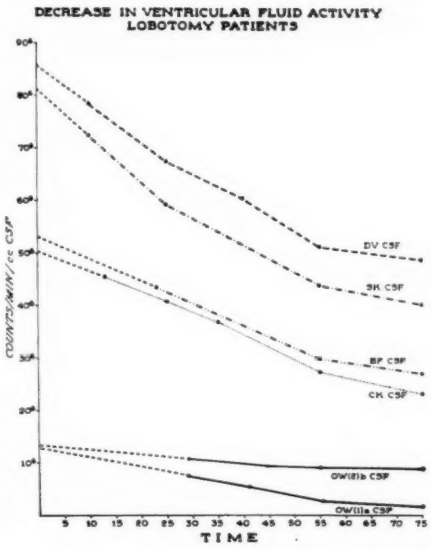


FIG. 5. The portion of the curve from time of injection (0) to the first point is extrapolated (dotted lines) by merely extending it to the zero point. Compare the ventricular disappearance curves in this graph with the superior longitudinal sinus uptake curves in the same patients (Fig. 2).

activity can be explained on the basis of differences in dosage (Table 1) as well as some difference in ventricular size with a variable dilution factor. The fall in activity apparently is a linear function with time, occurring at a fairly constant rate for 1 hour and then gradually slackening.

FIG. 6. Lateral view of pneumoencephalogram of patient O. W. Note enlarged ventricles and absence of gas in subarachnoid channels.

One patient (O. W.) was of considerable interest and studies were repeated 3 weeks after the original tests at the time of lobotomy. This patient had a marked communicating hydrocephalus, a total of 285 cc. of spinal fluid having been removed during a pneumoencephalogram prior to her lobotomy (Fig. 6). The etiology of this hydrocephalus could not be determined, although at the time of operation it was noted that the arachnoid was extremely opaque and thickened. The rate of uptake of $P^{32}$ in the superior longitudinal sinus and the decrease in ventricular fluid activity in the two studies are tabulated in Fig. 7. It is apparent that following the lobotomy there is a decreased uptake in the sinus as well as a decrease in the rate of disappearance from the ventricular fluid. The curve for the uptake in the sinus resembles that obtained in hydrocephalic infants. At the time of the second study the patient was suffering from severe increased intracranial pressure which was assumed to be due to blockage of the absorptive bed by blood. This had been antici-

TABLE 1

| Patient | Dose Microcuries | Total 24-Hour Urine Count | Per Cent Dose in 24-Hour Urine |
|---|---|---|---|
| | | *Lobotomy Patients* | |
| D. V. | 350 | $23.38 \times 10^6$ | 3.01 |
| S. K. | 350 | $23.07 \times 10^6$ | 2.97 |
| B. F. | 350 | $20.43 \times 10^6$ | 2.63 |
| C. K. | 250 | $12.26 \times 10^6$ | 2.21 |
| O. W.(1) | 200 | $7.903 \times 10^6$ | 1.78 |
| O. W.(2) | 200 | $3.338 \times 10^6$ | 0.752 |
| | | *Hydrocephalic Infants* | |
| D. B. | 200 | $1.798 \times 10^6$ | 0.43 |
| S. W. | 200 | $0.932 \times 10^6$ | 0.21 |
| D. S. | 300 | $1.132 \times 10^6$ | 0.17 |
| M. | 200 | $1.154 \times 10^6$ | 0.26 |
| J. P. | 300 | $11.521 \times 10^6$ | 1.73 |
| R. C. | 300 | $9.723 \times 10^6$ | 1.46 |

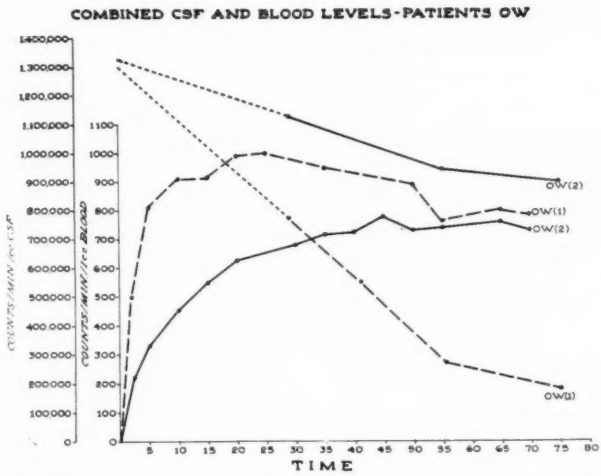


FIG. 7. The numbers (1) and (2) indicate the first and second study respectively.

pated since it was felt, as a result of her previous air study, that there was a rather delicate balance between the processes of formation and absorption of cerebrospinal fluid.

### *C. Hydrocephalic Infants*

Six infants with hydrocephalus, ranging in age from 3 to 8 months, were studied in similar fashion. Fig. 8 demonstrates the curves obtained of the uptake in the superior longitudinal sinus and Fig. 9 the rate of disappearance from the ventricular fluid. The blood curves of 4 of the infants (M., D. S., D. B., S. W.) were quite different from those obtained in the human and animal controls. Three of these patients had a communicating type of hydrocephalus as determined by dye studies, and one (M.) an obstructive hydrocephalus.

There is an immediate rather rapid rise in activity, but the maximum peak does not occur at the

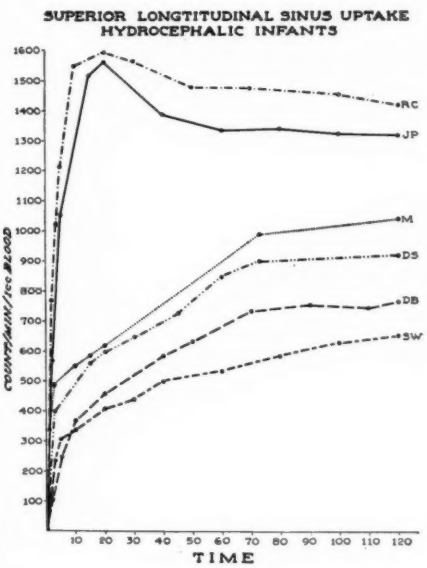


FIG. 8.

usual time of approximately 20 to 30 minutes. Instead there is a gradual, slow rise for the entire period of study, namely 2 hours. The level of activity obtained is likewise much lower than in the normal controls. However, in 2 infants (R. C. and J. P.) the curve has essentially a normal form and much greater uptake is seen. The hydrocephalus in each of these patients was a communicating type. The rate of disappearance of $P^{32}$ from the ventricular fluid is correspondingly slower in the first 4 infants, whereas in the latter 2, the slope of the curve is steeper and approaches that of the normal controls.

The percentage of the total dose of $P^{32}$ injected that was excreted in

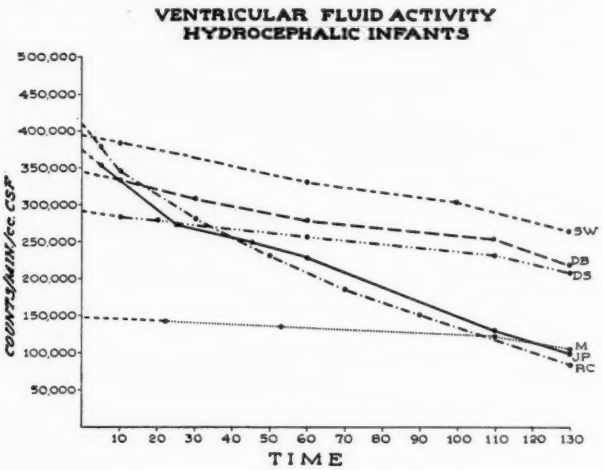


FIG. 9.

the urine of both the human groups during the first 24 hours following injection is tabulated in Table 1. For the control group this value ranges from 2.21 to 3.01 per cent. In the patient who was studied during and after lobotomy, it can be seen that the percentage of excretion of $P^{32}$ falls from a level of 1.78 per cent to 0.752 per cent at the time when there was increased intracranial pressure and apparent absorptive block. The percentage of urinary excretion for the 4 hydrocephalic infants whose rate of absorption of $P^{32}$ was slow is diminished, whereas the 2 infants with essentially normal curves likewise had a 24-hour excretion within the normal range.

The essentially normal curves and urinary excretion of the tracer in the 2 hydrocephalic infants (J. P. and R. C.) are of considerable interest. A possible explanation for the difference between these two groups of hydrocephalic infants would be that the 4 infants demonstrating slow uptake in the superior longitudinal sinus, a slow rate of disappearance from the ventricular fluid, and a decreased urinary excretion, had a type of hydrocephalus in which there is a definite block to the absorptive mechanism. In the re-

maining 2 infants it is suggested, as a result of these studies, that the cause of the hydrocephalus is due rather to an overproduction of cerebrospinal fluid than to a block in the cerebrospinal fluid pathways.

The choroid plexus of 1 of these infants (R. C.) was examined at autopsy some 6 weeks after the study was performed (Fig. 10). This patient had had a successful subarachnoid-ureteral anastomosis,[9] but expired outside the hospital from an acute upper respiratory infection. The choroid plexus grossly appeared to be, if anything, larger than normal and microscopic examination showed it to be essentially normal. This is in contrast to the marked fibrosis and atrophy of the choroid plexus seen in many infants dying with hydrocephalus.

FIG. 10. Coronal section of brain (patient R. C.). Note choroid plexus in floor of lateral ventricles.

One other consideration can be cited in favor of the possibility that there is a definite type of hydrocephalus that is due to an overproduction of fluid rather than a defect in absorption. The operation of choroid plexectomy or coagulation of the choroid plexus has had a notable success in some instances, whereas in others there has apparently been no improvement in the course of the hydrocephalus. It is possible that in the instances where this type of procedure has been successful, the etiology has been one of overproduction of fluid rather than a defect in absorption; and conversely, where the operation has been unsuccessful the underlying fault is in the absorptive process. The tracer studies described are suggested as a possible means of differentiating between these two types of hydrocephalus.

## SUMMARY AND CONCLUSIONS

The uptake of radioactive phosphorus ($P^{32}$) in the superior longitudinal sinus following its introduction into the ventricular system has been studied in dogs, in human subjects with normal cerebrospinal fluid dynamics, and in 6 hydrocephalic infants.

Reasonably consistent curves have been obtained for the rate of uptake of the tracer in the superior longitudinal sinus, its disappearance from the ventricular system, and the amount of urinary excretion of the tracer for the first 24 hours following its injection.

Evidence is presented that the main absorptive bed for the cerebrospinal fluid is not the arachnoidal villi of the pacchionian granulations, but lies

distal to this point and is presumably the capillaries and possibly the small veins of the pia arachnoid.

A decreased rate of uptake into the superior longitudinal sinus as well as a decreased rate of disappearance from the ventricles was found in 4 hydrocephalic infants, accompanied by a decreased 24-hour urinary excretion. In 2 hydrocephalic infants these values were entirely normal. The question arises whether the latter 2 cases may represent an overproduction of fluid as the cause for the hydrocephalus rather than a defect in the absorptive processes.

## REFERENCES


1. Bakay, L., and Lindberg, O. Studies on the rôle of the cerebrospinal fluid in brain metabolism as measured with radioactive phosphate. *Acta physiol. scand.*, 1949, *17:* 179–190.
2. Clark, W. E. Le G. On the pacchionian bodies. *J. Anat., Lond.*, 1920, *55:* 40–48.
3. Dandy, W. E. Where is cerebrospinal fluid absorbed? *J. Amer. med. Ass.*, 1929, *92:* 2012–2014.
4. Griffith, J. Q., Jr., Fry, W. E., and McGuinness, A. Experimental and clinical studies in hydrocephalus. With especial reference to the occurrence of papilledema. *Amer. J. Ophthal.*, 1940, *23:* 245–251.
5. Hassin, G. B. Cerebrospinal fluid. Its origin, nature and function. *J. Neuropath. exp. Neurol.*, 1948, *7:* 172–181.
6. Ingraham, F. D., Alexander, E., Jr., and Matson, D. D. Experimental hydrocephalus. *J. Neurosurg.*, 1947, *4:* 164–176.
7. Jones, H. B., Chaikoff, I. L., and Lawrence, J. H. Phosphorus metabolism of the soft tissues of the normal mouse as indicated by radioactive phosphorus. *Amer. J. Cancer*, 1940, *40:* 235–242.
8. Key, A., and Retzius, G. Studien in der Anatomie des Nervensystems und des Bindegewebes. *Stockholm: Samson & Wallin*, 1875–76, 2 vols.
9. Matson, D. D. A new operation for the treatment of communicating hydrocephalus. Report of a case secondary to generalized meningitis. *J. Neurosurg.*, 1949, *6:* 238–247.
10. Mott, F. W. The Oliver-Sharpey lectures on the cerebro-spinal fluid. *Lancet*, 1910, *2:* 79–83.
11. Scholz, R. O., and Ralston, E. M. The pathways of absorption of sodium ferrocyanide from the subarachnoid space into the venous system. *Anat. Rec.*, 1939, *75:* 365–371.
12. Weed, L. H. Studies on cerebro-spinal fluid. No. II. The theories of drainage of cerebro-spinal fluid with an analysis of the methods of investigation. *J. med. Res.*, 1914, n.s. *26:* 21–118.
13. Weed, L. H. Meninges and cerebrospinal fluid. *J. Anat., Lond.*, 1938, *72:* 181–215.
14. Woollard, H. H. Vital staining of the leptomeninges. *J. Anat., Lond.*, 1924. *58:* 89–100.

# STUDIES IN NEUROSURGICAL ELECTRO-ENCEPHALOGRAPHY

## 1. STANDARD ELECTRODE PLACEMENT

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PRACTICALLY every electroencephalographic worker has developed his own system of orientating electrodes on the heads of his patients. Providing certain fundamental technical requirements† are fulfilled, most of the systems thus evolved seem adequate for everyday requirements, and minor differences in electrode type and topography are probably of little significance.

However, this applies only in centres where the principal emphasis is on the recognition of paroxysmal dysrhythmias. When an attempt has to be made to correlate the spatial distribution of abnormal electrical activity with regional cerebral anatomy, as is the case in centres dealing largely with neurosurgical material, the actual method of electrode placement becomes of major significance. But as there is no precisely reliable method available for the accurate correlation of skull topography with regional brain anatomy, no universal standard can be prescribed.

Nevertheless, experimental results in this field depend greatly upon methods of electrode placement; so the present communication describes the method of orientating electrodes and the technique of recording employed in the studies made in the Nuffield Department of Surgery. It is to be understood that in ensuing reports the technique described in this paper has been followed, unless otherwise stated, and no further detailed description will be given. The method has been regularly employed in this Department for the last 18 months, during which time 2,200 records have been made from all types of clinical material at all ages.

No reference is made to the many other methods of electrode orientation employed elsewhere, as these have been discussed by the individual workers concerned.

### TYPE OF ELECTRODE

The electrode employed is the so-called "saline pad" contact electrode,[5] although solder disc electrodes affixed to the scalp with collodion have been used on some occasions. The former electrode consists of a silver bell-ended

* Beit Memorial Research Fellow.

† See Walter,[7,8] Williams and Gibbs,[9] Gibbs and Gibbs,[4] Cohn,[3] Hill and Parr,[5] and the recommendations of the American EEG Society.[1]

tube mounted in a moulded polythene holder,* and covered with a convex saline pad (Fig. 1) which is kept moist in saline solution. From time to time the electrodes are rechlorided by electrolysis in saline solution: and in the intervals between use they are stored with the pads immersed in salt solution.

These electrodes are applied to the scalp, after parting the hair and cleaning the skin with ether-alcohol or methylated spirit, with or without preliminary anointing of the area with some form of contact paste ("Bentonite" or "Cambridge Electrode Jelly" is usually used in this unit). They are held in place by a cap made of rubber strands tied under the chin ("Butywave" type†) or, in small children, by rubber bands traversing the scalp transversely and tied to another band encircling the whole head.

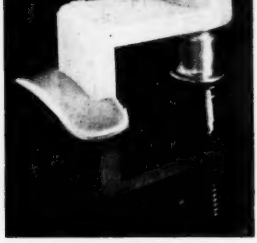

FIG. 1. The saline pad electrode holder used in these studies. The gauze pad is wrapped around the bell-shaped foot of the silver rod mounted in the plastic carrier.

With this method the electrodes sit firmly and with little discomfort to the patient, they are independent of any change of position of the head, and more electrodes can be added or their positions changed quickly. Interelectrode resistances of the order of 2,000 to 5,000 are regularly obtained, and there is no difficulty in securing satisfactory records with a minimal admixture of artifacts, under most experimental conditions. Sometimes electrodes are knocked off during a violent seizure or if the patient rolls over while asleep, but this can be avoided by controlling the position of the head; and in any case the displaced electrodes are easily restored.

This technique is entirely suitable for routine work in any centre, and is especially applicable when records have to be made from patients with recent scalp wounds, either operative or traumatic, as the electrodes can be placed around the wound more readily and more cleanly than with most other methods.

The only difficulty that may be experienced is a marked increase in electrode resistance due to rapid drying of the saline pads on hot dry days. The climate in England is such as to minimise this trouble, but in other countries it may be necessary to moisten the pads from time to time during recording; and this is easily done by dropping saline solution on them with an eye dropper, taking care to wet only the saline pad.

## SITING OF ELECTRODES

In order to determine the electrode pattern that would give optimal coverage of the whole brain, radiographic studies of the skulls of patients

* Manufactured by the Edison Swan Electric Company, Ltd., 155 Charing Cross Road, London W.C. 2.

† Manufactured by Biometica Ltd., Rampayne St., London S.W. 1.

with a variety of head sizes and shapes were made in anteroposterior and lateral projections, and theoretically desirable electrode positions were plotted on the X-ray films. Electrodes were then applied to the head in the plotted positions and the skulls were re-X-rayed.

Calculations were made in terms of various reference points on the skull surface in the hope that the most suitable patterns could be orientated by reference to such points, thus facilitating the work of the recordists. But it was found that none of the conventional methods of measurement were satisfactory in practice, and finally a pattern was determined by trial and error, the electrode distribution in which could be made with reference to the angle subtended by the plane of the electrode to Reid's base line at the external auditory meatus (Fig. 2).

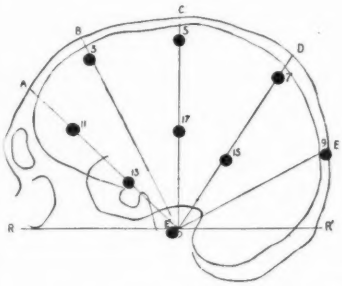


FIG. 2. Tracing from radiograph of skull, showing orientation of the full series of 18 electrodes, and their relation to Reid's base line (RR¹) and to the external auditory meatus (E¹). The average positions on adult heads are given in the accompanying table.

| Electrode Angle | Average Angle Subtended at E¹ | Average Distance from E¹ on Adult Heads | |
|---|---|---|---|
| | | Electrode No. | Distance (cm.) |
| RE¹A | 45° | 13 | 3.5 |
| | | 11 | 9 |
| RE¹B | 60° | 3 | 14 |
| RE¹C | 90° | 17 | 7 |
| | | 5 | 13 |
| R¹E¹D | 60° | 15 | 6 |
| | | 7 | 14 |
| R¹E¹E | 30° | 9 | 11.5 |

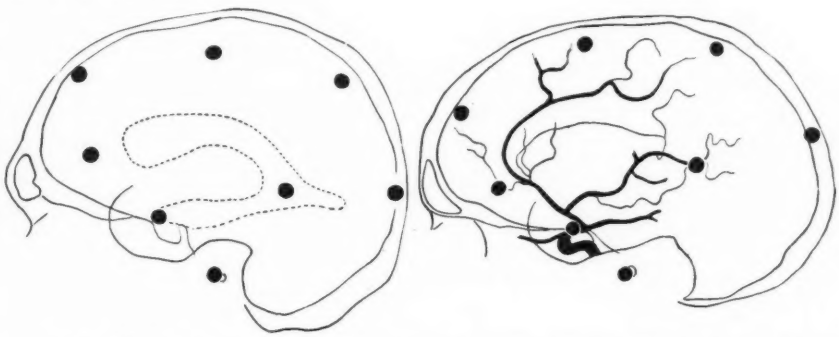

FIG. 3 (*left*). Tracing from pneumoencephalogram to show the relation of the standard 16 electrode pattern to the air-filled ventricular system.

FIG. 4 (*right*). Tracing from first film of a percutaneous carotid angiogram to show the relation of the standard 16 electrode pattern to the principal cerebral vessels and the main arterial fields.

The position of the electrodes was checked in relation to the ventricular system by X-raying the head after the ventricles had been filled with air and the electrodes applied (Fig. 3). They were also checked in relation to the main cerebral vessels (Fig. 4) by X-raying the head during carotid angiography, after silver clips had been fixed to the scalp in the position of the electrodes, and in relation to the underlying brain in the autopsy room, by a similar method.

## THE STANDARD PATTERN

As a result of this method of investigation the following pattern of electrode placement has been developed for routine use in this Department. Fourteen or more electrodes are applied to the head in the patterns indicated in Figs. 2, 5 and 6, the recordists siting them with reference to the external auditory meatus and Reid's base line. In certain cases two other electrodes are placed one in each auditory meatus, and used either as reference electrodes or as part of a bipolar pattern of exploration. Periodically, the constancy of the pattern has been checked by X-raying patients selected at random from the series examined by the various members of the Department, and it is found that the electrode positions do not vary by more than 1 to 1.5 cm. from the standard position as initially determined, once the recordists are practised in siting them. On other occasions the relation of the electrode positions to the underlying brain surface

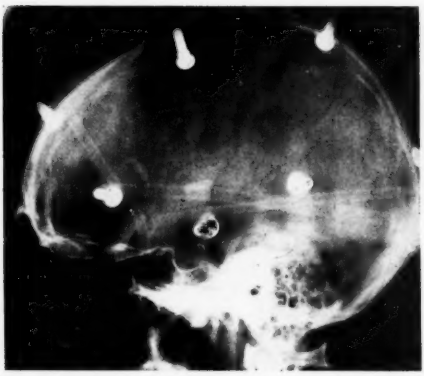

FIG. 5. Lateral radiograph of skull showing the orientation of the standard 16 electrode pattern on an adult skull. The ear electrode is displaced downwards from its usual position in the external auditory meatus to enable it to be seen.

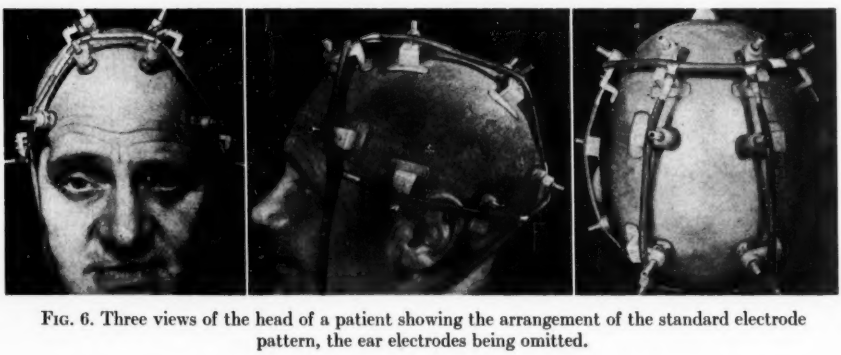

FIG. 6. Three views of the head of a patient showing the arrangement of the standard electrode pattern, the ear electrodes being omitted.

has been rechecked in the autopsy room, and a similar order of accuracy prevails.

## METHOD OF RECORDING

The following is the routine method of recording employed at the initial examination of every patient. Variations in the technique for special reasons will be described in the relevant papers to follow.

The records are made either on a Grass 3-channel or an Ediswan 6-channel apparatus, utilising an appropriate system of selector switching based on the standard pattern of electrode placement. After calibration, 8 runs are made in longitudinal and transverse planes (Fig. 7), the effects of eye opening and closing being tested in the course of at least 5 runs (in both planes).

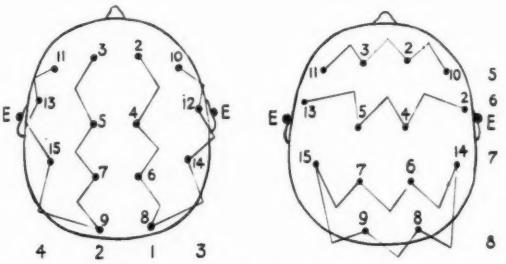


FIG. 7. Diagrams showing the electrode combinations in which the routine bipolar runs are made. The numbers below the left-hand figure and beside the right-hand one indicate the order in which the runs are made. Ear lead runs are always additional to this routine bipolar exploration.

The runs are made in bipolar fashion, first along the two parasagittal planes, superior and inferior, on each side, and then along each of the transverse frontal, precentral, postcentral and occipital planes. In some cases additional runs are made using the ears as reference electrodes or as part of the longitudinal and transverse bipolar system. Each run is of 50 to 60 seconds' duration, but longer when some special abnormality is being sought or studied. At the end of the resting record a run is made during 2 minutes' hyperventilation and for 2 minutes thereafter. Sometimes this hyperventilation period is increased; and the particular run employed for hyperventilation depends upon the appearance of the resting record, the transverse precentral plane being the one most commonly used with profit.

At times face leads are employed, and in special cases additional runs in other planes or with eccentric electrodes are employed. As yet no studies have been made in this unit using nasopharyngeal[6] or direct tympanic leads.[2] Whenever the exact location of a focal abnormality is in question, the patient's head is X-rayed with the electrodes *in situ* and the position plotted on the film. The same procedure is sometimes followed with air studies or angiography.

## CONCLUSION

This method of electrode placement and recording seems to be as satisfactory as one can get, allowing for the large variety of head shapes and sizes in patients of different ages. It seems to possess sufficient constancy in relation to a theoretical standard pattern in the hands of several operators to be of practical value, and the periodic radiographic control of electrode positions seems to be a useful measure. The technique has proved its worth not only in the study of paroxysmal dysrhythmias but also in the study of localised lesions such as tumours and abscesses, and in the search for epileptogenic foci. Details of these latter applications will follow.

Thanks are due to the members of the Staff of the Nuffield Department of Surgery and of the Department of Radiology for their cooperation in these studies, and especially to Miss F. M. Taylor and Miss B. L. Thomas, B.Sc., who have made nearly all the records upon which these studies are based. The drawings were made by Miss A. Arnott.

## REFERENCES

1. American Electroencephalographic Society. Reports of special committees, annual meeting, Atlantic City, New Jersey, June 1948.
2. Arellano, A. P. A tympanic lead. *EEG clin. Neurophysiol.*, 1949, *1:* 112–113.
3. Cohn, R. Clinical electroencephalography. *New York: McGraw-Hill Book Co., Inc.*, 1949, vii, 639 pp.
4. Gibbs, F. A., and Gibbs, E. L. Atlas of electroencephalography. *Cambridge, Mass.: L. A. Cummings Co.*, 1941, 221 pp.
5. Hill, D., and Parr, G. (Eds.) Electroencephalography. A symposium on its various aspects. *London: Macdonald & Co., Ltd.*, 1950, 438 pp.
6. MacLean, P. D. A new nasopharyngeal lead. *EEG clin. Neurophysiol.*, 1949, *1:* 110–112.
7. Walter, W. The location of cerebral tumours by electro-encephalography. *Lancet*, 1936, *2:* 305–308.
8. Walter, W. G. The technique and application of electro-encephalography. *J. Neurol. Psychiat.*, 1938, n.s. *1:* 359–385.
9. Williams, D., and Gibbs, F. A. Electroencephalography in clinical neurology. Its value in routine diagnosis. *Arch. Neurol. Psychiat., Chicago*, 1939, *41:* 519–534.

# THE CATABOLIC EFFECT OF CRANIOTOMY AND ITS INVESTIGATIVE TREATMENT WITH TESTOSTERONE PROPIONATE

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THE catabolic effect of various types of trauma and surgical procedures on body protein is well documented.[1,2,5,7,9] Several reports have appeared recently which indicate that in certain instances trauma to the brain or spinal cord may be followed by marked catabolic activity.[3,8,10] This study was undertaken in an attempt to evaluate the average catabolic activity, as reflected in urinary excretion of nitrogen which occurs after craniotomies that involve removal of intracranial tumors or cerebral tissue. We also have investigated the use of testosterone propionate as an anticatabolic agent in such cases.

## MATERIAL AND METHODS

Ten consecutive patients who were to be subjected to craniotomy and removal of an intracranial tumor or cerebral tissue or both, and who were in a reasonably good nutritional state, were selected as subjects for this investigation. During the first 5 days after operation daily estimations were made of the total nitrogen, creatine nitrogen and preformed creatinine nitrogen excreted in the urine. The day of operation was counted as the 1st postoperative day. The fecal excretion of nitrogen was estimated, inasmuch as there is no more than a normal amount of nitrogen in the stools during the posttraumatic catabolic period.[7] The nitrogen and caloric intake were accurately charted, but a special attempt was not made to regulate this intake. During the 5-day period of observation the concentrations of serum chloride, sodium and potassium were determined daily in each case. The first 5 consecutive patients (control group) were treated with the measures routinely employed by us during the postoperative period. In addition to these routine measures, the second 5 consecutive patients received 50 mg. of testosterone propionate intramuscularly for 6 days, commencing the day prior to operation. Inasmuch as we do not routinely employ tube feeding or the use of intravenous protein supplements during the immediate period after craniotomy, the intake of nitrogen of these patients during the first 48 hours after operation was practically zero. The average intake of nitrogen

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for the next 3 days was 6 to 7 gm. daily, while the average daily intake of nitrogen for the 5-day period of observation was 4 to 5 gm. in both the control group and the group receiving testosterone propionate.

## RESULTS

*Control Group of Patients.* Each of the 5 patients in the control group

TABLE 1

*Average daily urinary excretion of nitrogen and creatine nitrogen, and average daily nitrogen balance of 5 control patients during first 5 days after craniotomy*

| Case Number | Sex and Age, Yrs. | Diagnosis | Operation | Averages | | | |
|---|---|---|---|---|---|---|---|
| | | | | Urinary Excretion of Nitrogen, gm. in 24 hr. | Daily Excretion of Nitrogen, gm. per kg. body wt. | Urinary Excretion of Creatine Nitrogen, mg. in 24 hr. | Daily Nitrogen Balance, gm. in 24 hr. |
| 1 | M 45 | Bilateral olfactory groove meningioma | Bilateral frontal craniotomy (Soutar flap); subtotal removal of tumor | 15.5 | .22 | 95 | −11.0 |
| 2 | M 49 | Chromophobe adenoma of pituitary | Left transfrontal craniotomy; intracapsular removal of tumor | 15.0 | .20 | 88 | −10.0 |
| 3 | M 39 | Acoustic neurofibroma | Right suboccipital craniotomy; total removal of tumor | 12.8 | .19 | 205 | −8.0 |
| 4 | M 47 | Oligodendroglioma of right frontal lobe | Right frontal craniotomy; radical resection for glioma | 13.5 | .19 | 84 | −10.2 |
| 5 | M 60 | Meningioma of right sphenoid ridge | Right transfrontal craniotomy; total removal of tumor and involved dura; removal of osteoma | 11.0 | .16 | 192 | −7.0 |

demonstrated a negative nitrogen balance during each of the first 5 postoperative days. The average daily urinary excretion of nitrogen was 13.5 gm., while the average nitrogen balance was minus 9.2 gm. daily. The peak urinary excretion of nitrogen was reached on the 2nd and 3rd postoperative days. The highest urinary excretion of nitrogen in 24 hours was 18 gm., noted in Case 1 on the 2nd and 3rd postoperative days. The daily urinary excretion of creatine nitrogen averaged 129 mg. The highest excretion of creatine

nitrogen in 24 hours was 312 mg., noted in Case 3. None of the patients in the control group had achieved a positive nitrogen balance by the 5th postoperative day. Concentrations of sodium, potassium or chlorides in the serum were not significantly abnormal during the period of observation. Important data concerning excretion of nitrogen in the control group appear in Table 1.

TABLE 2

*Average daily urinary excretion of nitrogen and creatine nitrogen, and average daily nitrogen balance of 5 patients who received testosterone propionate during first 5 days after craniotomy*

| Case Number | Sex and Age, Yrs. | Diagnosis | Operation | Averages | | | |
|---|---|---|---|---|---|---|---|
| | | | | Urinary Excretion of Nitrogen, gm. in 24 hr. | Excretion of Nitrogen, gm. per kg. body wt. | Urinary Excretion of Creatine Nitrogen, mg. in 24 hr. | Daily Nitrogen Balance, gm. in 24 hr. |
| 6 | M 43 | Malignant glioma left frontal lobe | Left frontotemporal craniotomy; radical resection of tumor | 9.7 | .16 | 61 | −5.7 |
| 7 | M 42 | Astrocytoma (grade 3) right temporal lobe | Right temporoparietal craniotomy; radical resection of tumor | 9.3 | .13 | 126 | −5.3 |
| 8 | F 52 | Chromophobe adenoma of pituitary | Right transfrontal craniotomy; resection of right frontal lobe with subtotal removal of tumor | 5.1 | .09 | 86 | −4.1 |
| 9 | F 44 | Suprasellar meningioma | Right transfrontal craniotomy; subtotal removal of tumor | 5.6 | .09 | 41 | −5.0 |
| 10 | M 47 | Meningioma sphenoid ridge | Left temporal craniotomy; subtotal removal of meningioma | 6.5 | .11 | 236 | −4.2 |

*Patients Receiving Testosterone Propionate.* Although each of the 5 patients in this group demonstrated a cumulative negative nitrogen balance during the first 5 postoperative days, 2 of these patients demonstrated a slightly positive nitrogen balance by the 4th day. The urinary excretion of nitrogen averaged 7.2 gm. daily, while the average nitrogen balance was minus 4.8 gm. The highest concentration of nitrogen excreted in the urine in 24 hours was 15.7 gm., noted in Case 6 on the 2nd postoperative day. The daily urinary excretion of creatine nitrogen averaged 110 mg. The highest concentration of creatine nitrogen excreted in 24 hours was 244 mg., noted

in Case 10. Concentrations of sodium, potassium or chloride in the serum were not significantly abnormal during the period of observation. Table 9 shows significant data concerning excretion of nitrogen in the group of patients who received testosterone propionate.

## DISCUSSION

The results in our control group of patients generally confirm the report of Drew and associates[6] concerning loss of nitrogen after craniotomy. Although the wastage of nitrogen after craniotomy is not as severe nor as prolonged as that after burns, fractures of long bones, some gastro-intestinal operations, or severe injuries to the spinal cord,[1,3,5,7,9] this loss of nitrogen can constitute a critical problem in some malnourished patients undergoing intracranial surgical procedures. Inasmuch as the degree of nitrogen wastage appeared to be significantly less for patients receiving testosterone propionate than for patients in the control group, it is concluded that the administration of this drug in adequate amounts lessens the catabolism of body protein which is induced by the surgical procedure of craniotomy. Inasmuch as testosterone may produce retention of electrolytes and water,[4] the possibility that this drug might cause an increase of postoperative cerebral edema must be evaluated. Retention of electrolytes was not evident during these short periods of observation.

Profound loss of nitrogen, and other bizarre metabolic sequelae, have been associated with some intracranial lesions, particularly certain lesions affecting the frontal regions of the brain.[8,10] Marked catabolic activity is also the rule after severe injury to the spinal cord.[3] Inasmuch as the average loss of nitrogen after removal of intracranial tumors or cerebral tissue is neither extremely large nor prolonged, it seems reasonable to speculate as to whether injury to specific fiber tracts in the brain or spinal cord may be instrumental in inducing excessive catabolic activity. Such speculation has been advanced by Sweet and co-workers,[10] and McLardy[8] has presented evidence that bilateral injury to the subcallosal fasciculus of the brain may produce metabolic sequelae of sufficient magnitude to result in death from malnutrition. The fact that injury to a small segment of the spinal cord may induce a greater catabolic reaction than the resection of a large volume of cerebral tissue also invites inquiry into the possibility that qualitative rather than quantitative factors determine the degree of catabolic activity after trauma to, or operation on the central nervous system.

## SUMMARY

Patients undergoing craniotomy for brain tumor were observed to undergo a moderate catabolic reaction which was reflected in the increased excretion of nitrogen in the urine and a negative nitrogen balance for the first 5 days after operation.

The degree of nitrogen wastage that occurred after craniotomy was less

marked for the 5 patients who received testosterone propionate than for the 5 control patients who did not receive this drug.

## REFERENCES


1. Braasch, J. W. Protein metabolic response to trauma. *Int. Abstr. Surg.*, 1949, *88:* 473–483.
2. Browne, Hoffman, Schenker, Venning, and Weil. Study of the metabolic aspects of damage and convalescence in acutely injured, contrasting previously healthy subjects with previously debilitated patients. In: *Conference on metabolic aspects of convalescence including bone and wound healing.* New York: Josiah Macy, Jr. Foundation, 1945, *9:* 15–44.
3. Cooper, I. S., Rynearson, E. H., MacCarty, C. S., and Power, M. H. The catabolic effect of trauma of the spinal cord and its investigative treatment with testosterone propionate. Preliminary report. *Proc. Mayo Clin.*, 1950, *25:* 326–330.
4. Council on Pharmacy and Chemistry. Report to the Council: Estrogens and androgens in mammary cancer. A progress report. *J. Amer. med. Ass.*, 1949, *140:* 1214–1216.
5. Cuthbertson, D. P. Post-shock metabolic response. *Lancet*, 1942, *1:* 433–437.
6. Drew, J. H., Koop, C. E., and Grigger, R. P. A nutritional study of neurosurgical patients. With special reference to nitrogen balance and convalescence in the postoperative period. *J. Neurosurg.*, 1947, *4:* 7–15.
7. Howard, J. E. Protein metabolism during convalescence after trauma. Recent studies. *Arch. Surg., Chicago*, 1945, *50:* 166–170.
8. McLardy, T. Uraemic and trophic deaths following leucotomy. Neuro-anatomical findings. *J. Neurol. Neurosurg. Psychiat.*, 1950, n.s. *13:* 106–114.
9. Mulholland, J. H., Co Tui, Wright, A. M., and Vinci, V. J. Nitrogen metabolism, caloric intake and weight loss in postoperative convalescence. A study of eight patients undergoing partial gastrectomy for duodenal ulcers. *Ann. Surg.*, 1943, *117:* 512–534.
10. Sweet, W. H., Cotzias, G. C., Seed, J., and Yakovlev, P. Gastro-intestinal hemorrhages, hyperglycemia, azotemia, hyperchloremia and hypernatremia following lesions of the frontal lobe in man. *Res. Publ. Ass. nerv. ment. Dis.*, 1948, *27:* 795–822.

# AN EVALUATION OF THE TECHNIC AND RESULTS OF THE RADIOACTIVE DI-IODO-FLUORESCEIN TEST FOR THE LOCALIZATION OF INTRACRANIAL LESIONS*

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RADIOACTIVE di-iodo-fluorescein has been utilized in the study of 340 patients with the diagnosis of a space-occupying lesion of the central nervous system. We have correlated our findings with the preoperative clinical diagnosis, electroencephalography, pneumography, angiography, and with the surgical and autopsy findings. We have made postoperative and post-irradiation therapy tests and, finally, we have correlated all of these studies with the histopathological characteristics of the tumors.

The results indicate that this radioactive isotope dye test is a valuable diagnostic aid in neurosurgical problems, not only because of its high degree of accuracy in determining the presence of brain tumors, but also because of its relatively precise focal localization. The possibility of prognosticating in a general fashion the relative degree of cellularity and vascularity of the tumor also appears to be feasible.

In view of the relative simplicity, harmlessness and accuracy of this radiodye test, a more detailed elucidation of the technic, the advantages and the limitations of this new radioactive isotope tracer dye test is warranted.

Just as the neuroradiologist insists on a standardized technic, regarding milliamperage, time and kilovoltage in obtaining the best possible roentgenograms, proper positioning of the head and the tube, and the necessity of multiple and special views for adequate interpretation, so the isotopologist must be prepared for similar precision in instrumentation and technic. He must acquaint himself with all the ranges of normalcy at various time intervals and under various conditions such as post-ictal, post-traumatic, or post-irradiation therapy states, so that he may be able to interpret accurately the abnormal. Though a technician may become skilled in obtaining a good radiodye tracing, the interpreter must have an adequate background in neuropathology and neurophysiology to interpret the various states of dysfunction of the capillary endothelium, or the anaplastic proliferation of cells, in organic lesions of the central nervous system.

* Aided by the Grunow Surgical Fund.

Reviewed in the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions published by the authors are the results of their own studies and do not necessarily reflect the opinion or policy of the Veterans Administration.

The radioactive iodine used in this study was supplied by the Isotope Division, Oak Ridge National Laboratory, United States Atomic Energy Commission.

## INSTRUMENTATION

The radiation detection equipment[7] consists of 4 major components: (1) an end-window Geiger-Mueller tube; (2) a tube shield and allied mount; (3) an electronic indicator, scaler, or counting rate meter; and (4) a mechanical or graphic recorder (Fig. 1).

The counter tube is a commercially available Tracerlab TGG-2 mica end-window type, covered with a 250 mg./cm.$^2$ aluminum cap which effectively eliminates most of the $I^{131}$ beta radiations. It is the standard argon-alcohol filled tube operating at about 1500 volts, and has a mica window of about 2 mg./cm.$^2$, and

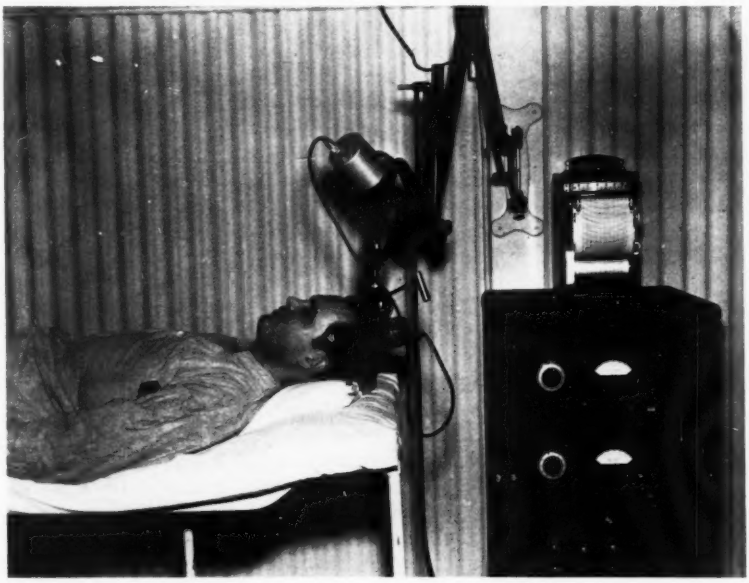

FIG. 1. The shielded TGG-2 Geiger tube is connected through an amplifier to a general radio counting rate meter, and the counts per minute are recorded on an Esterline-Angus milliammeter. The tube is maintained "normal" to the skull in this LF3 position (left superior precentral or frontal area). Readings are at least of 3 minutes' duration over each site. The most significant counting rates occur within ½ to 2 hours after the intravenous administration of 1.1 millicuries of radioactive di-iodo-fluorescein.

an $I^{131}$ gamma ray efficiency of about 0.5 per cent. The tube is calibrated with a high intensity standard before beginning the survey of the skull.

The tube sensitive diameter is 2.5 cm. The active detection area is found to be 1.2 cm. below the mica window. The tube and shield afford a resolution of 10 per cent for a 30° angle for a simulated tumor source of 25 cc. volumetric flask. The inverse square law for the source is closely followed by the end-window tube.

Other G-M tubes have been used, and have given basal radiodye concentrations which parallel the normal ranges obtained with the one described above, being either slightly above or below, but with the same general configuration on the tracing for the same site and time interval. Obviously, the numerical value of the

counts observed will depend upon the type of G-M counter tube, the shielding, the site, and the time after injection.

The tube shield usually employed has a lead thickness of 1.2 cm., equal to 4 H.V.L. of $I^{131}$ gamma rays. It extends 1.2 cm. beyond the end of the tube, enscribing a solid angle of almost $2\pi$. This resetting of the G-M tube within the lead shield provides for a very wide geometry and greater localization. Maximum flexibility is achieved by mounting the shield and tube in a 360° yoke and swivel (or on small camera tripod heads), which in turn is set on a wall-mounted dental x-ray arm.

The tube is connected to a pre-amplifier and into a modified General Radio, Type 1500-A, Counting-Rate Meter. This device integrates the radiation pulses over a pre-selected time interval and records the rate as a current output on an Esterline-Angus, 0–1 m.a. recording milliammeter.

A 1000 c.p.m. full scale range is used, with a maximum equilibrium time constant of 2 minutes for full scale deflection, and proportionately lower periods for different percentages of the full scale. A minimum reading of 3 minutes' duration is taken at each site after equilibrium has been reached. This period will allow for a maximum probable error of $\pm 2$ per cent of the average reading figured by the method of equal areas at a counting rate of 700 c.p.m. on a recording milliammeter. All rates below 400 c.p.m. require less than 1 minute readings for 2 per cent accuracy. The recorder is run at a convenient speed of about 3 minutes per $\frac{1}{2}$ inch.

## TECHNIC

Stable radioactive di-iodo-fluorescein free from loosely-bound iodine$^{131}$ is dispensed by Abbott Laboratories in a sterile 8–10 per cent solution, the specific activity of which is approximately $1.5 \times 10^{-5}$. Iodine$^{131}$ emits two beta particles (0.3, 0.6 MEV) and four gamma rays (0.08, 0.26, 0.34, 0.6 MEV). The radiation detected by the G-M tube is mainly the 0.34 MEV gamma ray, for which the tube has an efficiency of 0.5 per cent. The half-life of $I^{131}$ is 8 days.

An intravenous injection of 1.0 to 1.2 mc. (average 1.1 mc.) in the adult is given into the antecubital vein with precautions to prevent contamination of the skin of the patient's forearm by the placement of disposable paper thereon, and of the operator's hands, by the wearing of non-sterile gloves. Allowance, of course, is made for decay since production. The volume usually injected is between 0.7–3.0 cc. Depending upon the potency, a 1 cc., 2 cc., or 5 cc. syringe is used with a 20-gauge needle. To avoid bubbles of air, and for greater accuracy in dosage, the syringe should be "wetted" to above the required mark, with the radiofluorescein; then, the dye should be emptied into the container, and finally drawn back up the syringe to the designated volume for that day's dose. The routine precautions advised by AEC are also adhered to, and film badges and pocket electroscopes are checked weekly to prevent overdose of irradiation by the operator.

If any difficulty is expected in entering the contemplated vein, then an intravenous saline apparatus is first used, and the radiofluorescein is then inserted through the rubber tubing near the hub of the needle. The syringe is always washed through with the patient's blood to ensure that all of the dye has been given, before the needle is withdrawn.

After the radiodye is administered, the tube is placed in the LF7, or inferior anterior temporal area, and is kept there until the counts reach a plateau. This may vary from 15 to 40 minutes, and apparently depends upon the state of function of the liver and kidneys, which are the main excretory organs for the radioactive dye. Differential counts during this downward sloping of counts per minute should

*not* be done, as they will yield fallacious results. As soon as the downward curve has straightened out for 3 minutes or more, then the tube is changed to the RF8 area, i.e., the symmetrical anterior temporal area on the opposite side of the skull.

As seen from the pictorial chart (Fig. 2), a minimum of 32 different positions are then surveyed with the G-M tube, which covers every area of the skull on and above Reid's base line, if the 2 inch-diameter tube is used. These sites include 13 symmetrical positions on each side of the skull, 2 prefrontal (PF), 3 frontal (F), 3 central (C), 3 parietal (P), 1 occipital (O), and 1 suboccipital (O5, 6)—with the even numbers representing the right half, and the odd numbers the left half of the skull. Six midline positions are also routinely surveyed, i.e., mid-prefrontal, mid-frontal, mid-central, mid-parietal, mid-occipital, and mid-suboccipital.

The tube is placed directly on the scalp and is maintained "normal" to the skull, that is, at right angle to the tangent at that particular position under study. Readings are at least of 3 minutes' duration over each site, and are repeated over abnormal areas at frequent intervals of time from 20 minutes to 4 hours after injection of the dye. The counts per minute are visually displayed and continuously recorded on the Esterline-Angus tracing, so that the abnormal concentrations can readily be diagrammatically transposed and recorded on the pictorial chart.

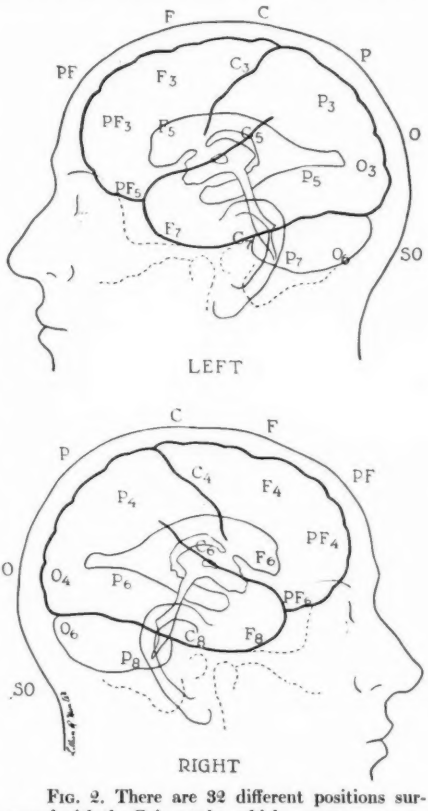


FIG. 2. There are 32 different positions surveyed with the Geiger tube, which covers every area of the skull on and above Reid's base line. These include 13 positions on each side of the skull, 2 prefrontal (PF), 3 frontal (F), 3 central (C), 3 parietal (P), and 2 occipital (O), besides 6 midline positions. It is essential that all these areas be checked within the significant ½ to 2½ hr. interval after radiofluorescein administration, because readings after 3 to 4 hr. are only confirmatory.

Within a minute or two after the injection of the dye, the radioactivity at the surface of the head is at a maximum. This decreases rapidly over the next 10 to 40 minutes, until a plateau is observed. After this interval, and for the next 1½ to 2 hours, the decline in counts is very gradual (Figs. 3 and 4) so that symmetrical positions can be accurately studied, if care is taken to match properly areas on each side of the skull within 3 to 5 minutes. The most significant counting rates occur within ½ to 2 hours after the administration of the radiodye; hence, suspected areas of involvement must not only be rechecked several times during this period, but must also be compared to the concentrations in adjacent areas, so as to delineate not only the main focus of the lesion, but also its extent. The counting rates during this

pertinent period, using the equipment described, is of the order of magnitude of 200 to 1200 c.p.m.

It is essential to count at least all 32 sites, but, since there is only a limited significant time interval of about 2 hours, the order of the performance of the counting should vary so that the suspected areas are measured at least 2 to 3 times, for greater accuracy. At the end of 3 to 4 hours, the readings are only confirmatory, for the differential concentrations are no longer striking.

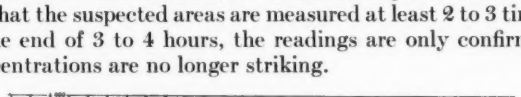


FIG. 3. Normal radioactive di-iodo-fluorescein concentrations in counts per min. on an Esterline-Angus tracing, at time intervals from 30 min. to 1¼ hr. after intravenous administration of 1.1 mc. of the dye. Symmetrical areas on each side of the skull are studied as simultaneously as possible within 3 to 5 min. after a "plateau" is reached. Note that in a normal patient, the variations over symmetrical sites are from 0 to 40 c.p.m. and that those over adjacent areas have a characteristic normal variation as well. Compare the left parasagittal frontal area to the left anterior temporal lobe (LF3 to LF7). Most of the non-space-occupying intracranial lesions fall within just such a range, and include patients with hypertensive cerebrovascular accidents, cerebral thrombosis, ruptured cerebral aneurysm, meningovascular lues, or chronic arachnoiditis.

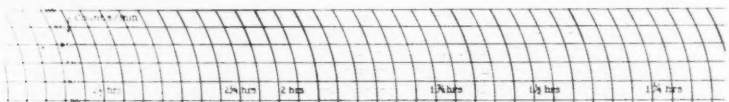


FIG. 4. Continuation of tracing shown in Fig. 3, at 1¼ to 2½ hr. after administration of the dye. Note gradual diminution of concentration of dye as test period continues.

## "NORMAL" RADIODYE CONCENTRATIONS

Just as the radiologist is acquainted with the normal variations in the ventricular system, or angiographic patterns of the brain, so the isotopologist must be aware of the normal range of radiodye concentrations at specific time intervals and for specific areas of the brain. The 32 different locations in the skull normally vary in their radiodye concentrations at the same interval of time following the radiofluorescein administration.

At least 10 to 20 "normal," or "non-tumor," patients should be given an intravenous injection of 1.1 mc. of radiodye and a chart then made of the radiodye concentrations for each of the minimal 32 sites chosen to cover the topography of the skull. These values can be recorded on the Esterline-Angus chart paper that is supplied with their automatic recorder, and the various ranges of "counts per minute" concentrations at each site at 30-minute intervals will be known for the first 3 to 4 hours after the injection.

It has been noticed that, after a plateau is reached for any one position, the variation of the readings at that site will not be greater than 20–40 c.p.m., regardless of whether the reading is 2 minutes or 12 minutes in duration. We use an average of 3 minutes at each site. Time must be permitted for the lag of the machine to occur, or the mechanical adjustment time for the change from one reading to another, before the plateau or flattening of the curve occurs. This lag is partially due to the inherent drag in the recording pen of the Esterline-Angus milliammeter. Two to 3 minutes after this occurs, the readings are statistically highly accurate.

If differences of over 40–50 c.p.m. occur at any 2 symmetrical sites, then these positions should be checked immediately. If the readings now show differences less than those considered pertinent (40 c.p.m.) it is probable that the tube was not symmetrically placed, or was somewhat angulated and not flush with the skull, or perhaps that there was movement of the patient. At any rate, every abnormality, be it pertinently high or not, must be re-checked not only immediately, but again within $\frac{1}{2}$ hr., and at various $\frac{1}{2}$ to 1 hour intervals thereafter. It is the presence of a persistent, and not a transitory, pertinent difference of radiodye concentrations that indicates the presence of an organic lesion.

## THE IMPORTANCE OF SIMULTANEOUS SYMMETRICAL READINGS

Ideally, the most accurate differences would occur if the readings over symmetrically chosen areas occurred at the very same instant of time. However, until multi-channel Geiger-tube reading machines are further perfected, readings should be made as simultaneously as possible, and, according to our standards, these should be within 3 to 5 minutes. However, if comparisons are made after 15 to 30 minutes (when, at times, in a somewhat restless patient one may find it convenient to record 2 or 3 different positions on one side of the skull, before contrasting these with their symmetrical mates on the opposite side), it will be noted that a gradual slope or decrease in the values at that site does occur with the passage of such an interval of time. This would, therefore, permit discrepancies to appear, since the differences would then exceed the permitted 20–40 c.p.m. expected between symmetrical sites in normal cases. Reference to the plotted concentrations on the proposed normal chart will help to clarify this important feature.

The above is of particular importance when the organic lesion is a relatively acellular, hypoplastic, or avascular one, such as an astrocytoma or calcified oligodendroglioma; or, a cystic degenerative or necrotic lesion. In these instances, the differences are only between 40 to 90 c.p.m., with the records as a whole being just above the highest expected normals at any particular interval of time. However, if the lesion is a highly anaplastic, cellular one, or one with proliferative new blood-vessel formations as well, then the resultant increased permeability causes such high concentrations of radioactive dye that the readings are definitely pertinent because of their heights (80 to 200 c.p.m. differences), and they persist even up to 4 hours following the intravenous administration of the dye. This is particularly

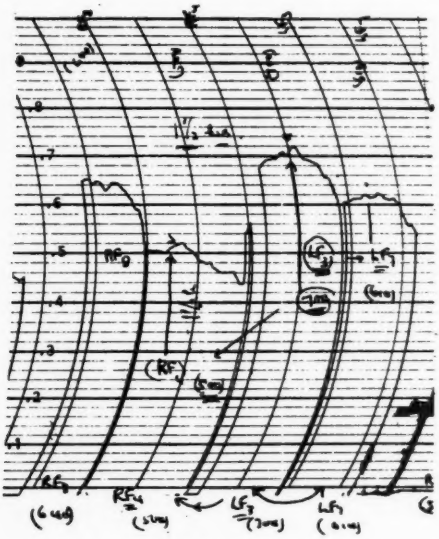

FIG. 5

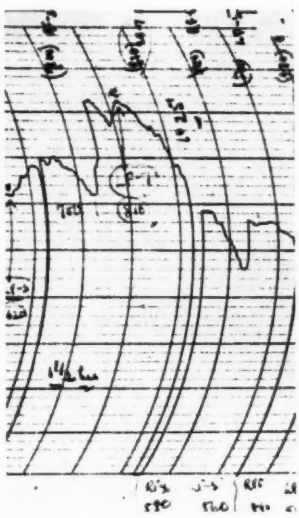

FIG. 7

FIG. 5. The site of the highest radiodye concentration is LF3 (left parasagittal precentral area) where the c.p.m. are 700, as compared to 500 on the right side, RF4. Normally, a difference of only 0.40 c.p.m. exists. The adjacent basilar site is usually 100 c.p.m. higher at this period of time (1½ hr.). However, here the parasagittal vertex reading is 90 c.p.m. higher than LF7 (610 c.p.m.), showing a complete reversal from the normal dye concentrations. Actual graph recording with working notations.

FIG. 7. Portion of graphic tracing at site of an extensive glioblastoma multiforme in left temporal lobe, proved at surgery and at autopsy to be accurate in its focal localization. The radiodye concentration at LF7 is 810 c.p.m. 1½ hr. after administration, as compared to 700 at RF8, the same basilar position on the opposite side, a difference of 110 c.p.m. Note that the adjacent positions LF5 (560) and RF6 (580) show 200 c.p.m. less than the tumor LF7 (810) and differ only 20 c.p.m. from one another.

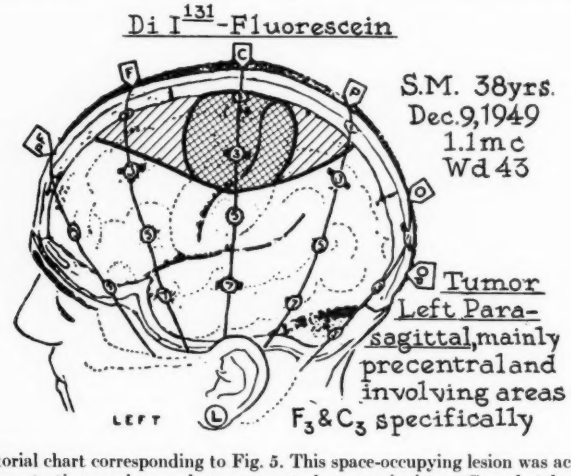


FIG. 6. Pictorial chart corresponding to Fig. 5. This space-occupying lesion was accurately outlined by radiodye concentrations and proved at surgery to be a meningioma. Cross-hatched area represents superficial portion of tumor. Remainder of outlined area was occupied by the meningioma that was present beneath the cortex.

true in the highly cellular meningiomas (Figs. 5, 6), glioblastomas (Figs. 7, 8), carcinomas and sarcomas, if they do not show marked cystic or necrotic changes. Our only errors have occurred in just such avascular, acellular, non-radiodye-accumulating areas.

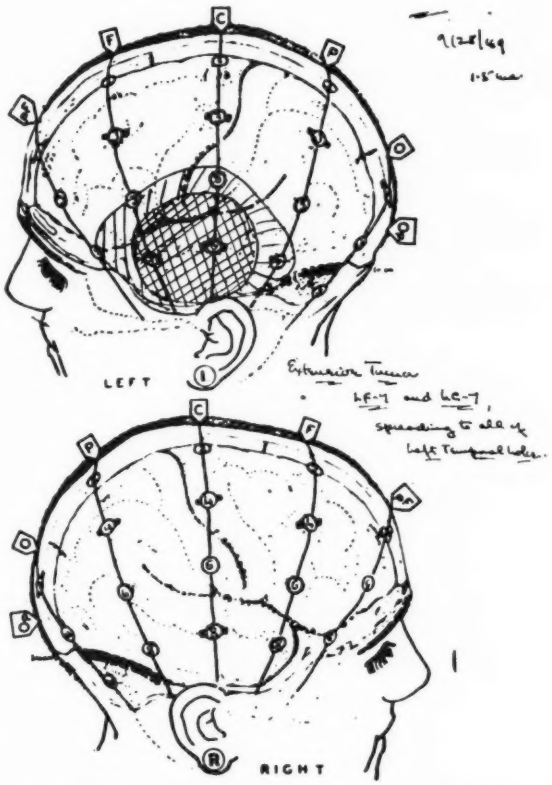


FIG. 8. Pictorial representation of tracing in Fig. 7, showing actual extent of the large glioblastoma multiforme.

## SPECIAL POSITIONS

Emphasis should be placed on the importance of placement of the tube on or even slightly below Reid's base line, with the reading part of the tube centered on the malar bone, or external auditory meatus (Areas F7, 8, and C7, 8 in Fig. 2) to pick up the radiations from the anterior temporal lobe, hippocampus, pituitary, brainstem, and deep temporal lobe. High concentrations here will determine the presence of such lesions, despite the fact that the symmetrical readings will be equidis-

tant from the center in such midline lesions. This finding may also be true in lateralizing lesions that are extensive enough to cross the midline. In lesions that are close to the midline in the middle cranial fossa, such as pituitary tumors extending out under the temporal lobe, or hippocampal tumors near to the midbrain, the basilar readings will again be high, with slight differences of only 40 to 70 c.p.m. to signify lateralization of the lesion. Placement over the mastoid (P7, 8) is made to detect posterior fossa or cerebellopontine-angle lesions.

The importance of the external occipital protuberance in differentiating supra- from infratentorial lesions must also be emphasized (Figs. 9, 10). To detect parasagittal lesions, particularly meningiomas, midline readings in addition to the symmetrical readings have proven to be of tremendous value.

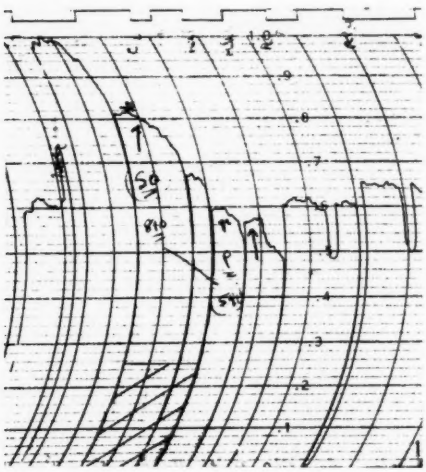

FIG. 9. Patient D. C. clinically showed signs and symptoms of a right parietal lobe neoplasm. Ventriculography was equivocal, demonstrating only mildly enlarged lateral ventricles. Radioactive fluorescein study revealed a very high tumor concentration in posterior fossa and upper cervical cord. At surgery, a vascular mixed-cell astrocytoma was partially removed from this site. Note 3½ hr. after administration of radiodye, the concentration in the middle posterior fossa or mid-suboccipital (SO) area is 810 c.p.m., which is 220 c.p.m. more than the midparietal (P—590)—a difference of 7 times the expected normal variation of 30, at this period of time. Also note that the total concentration of 810 is 560 c.p.m. above the highest normal value of 250 (see cross-hatched area) ever noted for the mid-suboccipital area at 3½ hr. These readings are highly significant of a vascular and cellular tumor.

## EFFECTS OF CHANGES IN ENDOTHELIAL PERMEABILITY

Differences in vascularization of intracerebral neoplasms have been emphasized since Virchow,[18] and most recently have been emphasized by the advanced histologic studies of Hardman,[9] Sahs and Alexander,[16] and Gough.[8]

The selective deposition of the radiodye within tumor tissue appears to be dependent mainly upon the state of the capillary endothelium, and the radiodye concentrations are directly proportional to the angio-architectural histopathological patterns. Previous experimental studies have proven that changes in endothelial permeability permit the exudation of foreign substances such as vital dyes.[4,6,11] Our studies tend to confirm these older observations.[5] It is possible that the increased cellularity of a tumor may also be responsible for the increased uptake of the radiodye. This may be due either to some intracellular enzyme or to some "spreading factor" or hyaluronidase-like substance, which has its effect upon the cement substance be-

tween the endothelial cells of the terminal capillaries, thereby secondarily increasing their permeability.[17]

Contrary to the impressions of Moore and his associates,[12,13,14,15] we believe that the degree of vascularity of a lesion is a major factor, since in our studies the highest radiofluorescein concentrations occur within the first hour

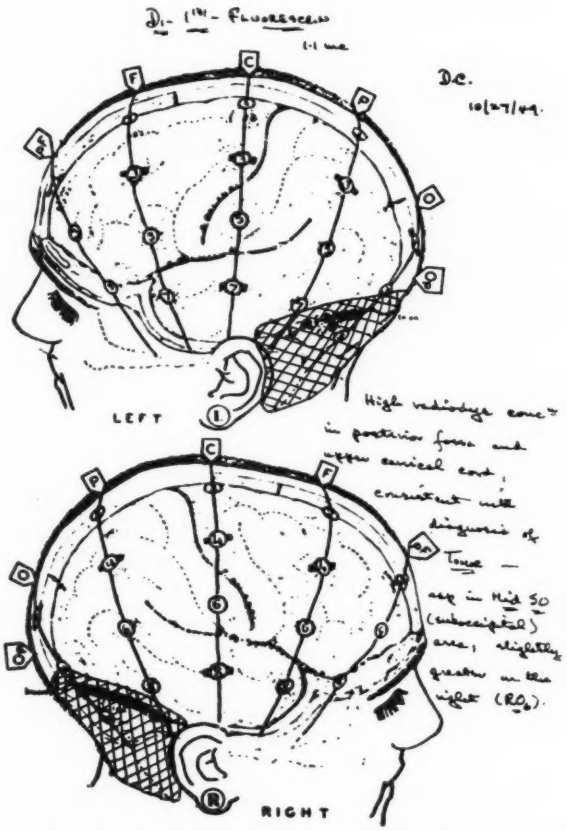


FIG. 10. Pictorial chart used for recording the graphic record in Fig. 9, in which the abnorma concentrations are diagrammatically transposed and recorded.

after the administration of the radiodye. We believe that it is the endothelium of the terminal capillaries that is of major importance, and not that of the larger blood vessels, since the latter do not share in the nutritional balance of the tissues and since we have been able to demonstrate that intracranial aneurysms yield relatively normal radiodye studies.[1,5] These features have been further supported by Broman's studies[3] from which he concluded

that tumors of the brain lack the specific semipermeability function of the blood-brain barrier.

Our in vitro biopsy studies on tumor tissue removed at surgery also show that the more vascular and more cellular tumors have higher radioactivity than the relatively avascular and acellular ones, and that cysts yield even less radioactivity than the normal brain itself.

## INTERPRETATION OF ABNORMALITIES

If the observed concentrations in a brain tumor suspect patient are 100 to 600 c.p.m. more than ever seen in the highest recorded normal at that particular time interval, then pathological endothelial permeability disturbances must exist at that point. These are indicative of an organic lesion, be it strictly vascular or neoplastic in nature. If cerebral trauma is suspected, whether that trauma is due to an injury, to a recent epileptic seizure, to a recent airstudy, or to a recent hematoma, then, a repeat study, performed 10–14 days later, will show a decreased radiodye concentration, consistent with the regressive vascular disturbances occurring in such lesions 2 weeks following the more acute episode. On the contrary, if the radiodye concentration still remains high, or becomes even higher, then it is suggestive of a *progressive* vascular endothelial lesion, such as may be secondary to dedifferentiation changes in anaplastic neoplasms, or to the effects of large doses of deep x-ray.

Recurrent tumors, regardless of their initial classification, show an increased uptake of radiodye, because of their increased cellularity, relative anaplasia, and atypical, hyperplastic, relatively undifferentiated new capillary formations, since the latter are now not capable of the highly selective permeability function of more differentiated blood vessels.

## LIMITATIONS OF THE RADIODYE TEST

The radiodye test does not differentiate an acute infection from an anaplastic tumor, since the disturbed capillary permeability in both types of lesions will result in an increased exudation of dye. However, if the infection has gone beyond the stage of "cellulitis," and a well-encapsulated abscess results, with central liquefaction necrosis and the absence of new blood vessels, then the radiodye has no deranged blood vessels to escape from, and hence normal concentrations are the result. This same explanation is pertinent in differentiating an acute intracranial hemorrhage, with its resultant increased vascularity, perivascular "cuffing" and surrounding edema, from a chronic subdural or intracerebral hematoma, with its thickened, relatively avascular, highly fibrosed capsule and its large central, chocolate cyst. The latter will yield either normal readings, or frequently even lower than normal, dependent upon the amount of the cystic contents. In a cystic degenerative tumor, only the actively growing tumor tissue concentrates the radiodye, whereas the cystic portions actually have a diminished uptake. When the preponderance of cyst fluid over tumor cells and tumor capillaries is too

great, the radiodye concentrations are not significantly increased, thereby giving rise to most of the errors expected to be encountered with this method of diagnosis.

## RADIOLOGICAL HAZARD AND OTHER REACTIONS

There have been no major untoward reactions. The patients have been comfortable; about 6 have had mild paresthesias of the finger tips and 2 have been nauseated, and 1 patient with an intracranial tumor had a seizure on the table for the first time.

Studies of the distribution and excretion of radioactive di-iodo-fluorescein have been made in human beings, dogs and rats.[10] The biological half-life in man is 4 days. The highest concentration after the initial maximum occurs in the thyroid gland, and the dose of radiation delivered to this tissue is about 8 equivalent roentgens. This dose of radiation is substantially less than that received by patients tested with 50 microcurie doses of radio-iodine in studies of thyroid function. The other tissues of the body retain considerably smaller amounts of the radiodye, and in none of the dogs was significant radioactivity detectable 7 days after the administration of 25 microcuries/kg., or twice the usual dose in human subjects. We believe that there is no significant hazard to the patient from the use of di-iodo-fluorescein in amounts of 1.0–1.2 millicuries.

## CONTRA-INDICATIONS

In contradistinction to other neurosurgical diagnostic tests, such as angiography, there have been no contra-indications with regard to age, very advanced arteriosclerosis, recent thrombotic or embolic episodes, acute intracranial hemorrhage, hypertension, or cardiac decompensation. Nor has there been any morbidity or mortality from the radiodye tests as there has been in some cases of pneumography, particularly ventriculography. This test gives better results in the presence of increased intracranial pressure, since the vascular permeability changes are greater.

## EVALUATION OF ERRORS

In the 340 tumor suspect cases studied, there were 17 errors made, in 10 of which the records were abnormally high and suggestive of an organic lesion but showed either false, or no definite, localization. These included 2 highly necrotic glioblastomas, 2 markedly necrotic, cystic, metastatic carcinomas, 2 calcified, gelatinous, degenerative oligodendrogliomas, 1 old, thickly encapsulated abscess, 2 cystic astrocytomas of the posterior fossa and 1 extradural lymphoblastoma. The other 7 were complete misses, and the records were within normal limits. These included 2 markedly necrotic, degenerated glioblastomas, 1 fibrillary astrocytoma with calcification and degeneration, 1 medulloblastoma of the posterior fossa, 2 cm. in size, 1 avascular granulomatous cyst of the posterior fossa, and 2 degenerated acoustic neurinomas $1\frac{1}{2}$ cm. in size.

## RESULTS

In all of the 340 cases, there were only 17 proven inaccuracies, making a total accuracy of 95.0 per cent for the radioactive di-iodo-fluorescein test in the detection of intracranial lesions.

There was 90 per cent accuracy in the 150 histologically verified space-occupying lesions of the central nervous system, which included 60 gliomas, 19 meningiomas, 17 metastatic carcinomas and sarcomas, 12 pituitary tumors, 8 spinal cord tumors, 2 cerebellar hemangioblastomas, 5 acoustic neurinomas, 1 melanoblastoma, 3 unclassified tumors, 8 subdural hematomas, 4 intracerebral hematomas, 3 cerebral abscesses, 2 arteriovenous fistulas, 2 granulomatous cysts, 1 porencephalic cyst, 1 epidermoid cyst and 2 focal arachnoid cysts. Fifty-two of the 60 gliomas studied were accurately diagnosed, and these included 29 glioblastomas, 22 astrocytomas, 5 oligodendrogliomas, 1 ependymoma and 3 medulloblastomas. A positive radiodye test was recorded in 7 of the 8 verified tumors of the spinal cord.

Besides these 150 microscopically verified space-occupying lesions, there were 17 grossly verified presumptive gliomas which were surgically treated and proved to be inoperable and are, at this time, microscopically unverified. All of these tumors were accurately diagnosed and localized with the radiodye test. This group included 11 patients with brainstem tumors, 6 of which had ventriculo-cisternostomy performed, and 6 with deeply seated, close to the midline, temporal lobe tumors. In addition, there are 25 other patients with presumptive space-occupying lesions who are awaiting surgical verification and/or further observation. The remaining 137 of the 340 tumor suspect patients were thought not to have a space-occupying lesion by this test, and this diagnosis was supported by surgical exposure in 16 instances, air studies in 91 instances and/or angiography in 7 instances.

## DISCUSSION

The affinity of radiodye for tumor tissue is related to the cellularity and vascular pattern of the tumor. The more malignant the neoplasm the greater is the radiofluorescein concentration. Metastatic carcinomas and sarcomas give counts in the highest differential range. Next are the glioblastomas and the vascular cellular meningiomas. The astrocytomas and oligodendrogliomas show the lowest differential count of all the tumors, coinciding directly with the relative microscopic scarcity of capillaries in these tumors. There is relatively little or no concentration of dye over the site of chronic, subdural hematomas since these are relatively avascular lesions. The radiodye concentrations over large cysts are even lower than other adjacent normal brain tissue. In a cystic degenerative tumor only the actively growing tumor tissue concentrates the radiodye, whereas the cystic portions actually have a diminished uptake.

The negative findings also proved to be 95 per cent accurate and were of equal importance in the differential diagnosis of cerebral neoplasms, especially from such lesions as hypertensive or thrombotic cerebrovascular accidents, perichiasmal arachnoiditis, meningovascular syphilis, and rup-

tured intracranial aneurysm, particularly in the presence of papilledema or Jacksonian epilepsy.

Localization proved to be much more precise than with electroencephalography, or pneumography, whenever verification was obtained at surgery or at autopsy. Pneumography is about 65 per cent focally and 85 per cent diffusely accurate; while electroencephalography is only 45 per cent focally, and 60 per cent diffusely accurate. Tumor recurrences can be demonstrated readily with this technic. Postoperative deep irradiation therapy causes an increased concentration of radioactive di-iodo-fluorescein in the more malignant intracerebral neoplasms.

Special technics of counting have been evolved, so that the accuracy of localizing midline tumors, such as those of the pituitary, brainstem, or posterior fossa, is as accurate as that of localizing the more superficially situated cerebral neoplasms.

With this apparatus and technic, the limitations of the test have proven to be very few, if due regard is had to accurate, painstaking, consistent placement of the Geiger tube on the skull, and if suspicious areas are rechecked and compared to symmetrical and adjacent areas of the skull. The test requires patience and time. Space-occupying lesions in every area of the skull have been localized accurately. Occasionally, localization is more diffuse, and even lateralization is difficult; in all these cases, the tumor is at or near the midline, or has actually crossed the midline. In several instances, lesions that showed no localizing symptoms upon clinical examination and in which pneumography did not aid, were accurately localized with the radiodye test, as proven at operation or autopsy.

Pneumoencephalography, and particularly ventriculography, have been highly successful in the diagnosis of brain tumors. However, besides the failure in a certain percentage of patients to localize, or even to lateralize a tumor by these means, there is real danger involved in patients with increased intracranial pressure. In contrast, the radiofluorescein test has proven to be entirely safe and harmless in all cases, and also gives more accurate information as to the exact site within the lobes.

## SUMMARY

The technic, the advantages and the limitations of the radioactive di-iodo-fluorescein test for the localization of intracranial lesions have been elucidated in detail, in view of the relative simplicity, harmlessness and accuracy of this newer diagnostic procedure.

In 340 patients suspected of having central nervous system tumors, there were only 17 proven inaccuracies, making a total accuracy of 95 per cent for the radioactive di-iodo-fluorescein test in the detection of intracranial lesions verified by surgery or corroborated by pneumography. The affinity of the radiodye for tumor tissue is related not only to the degree of cellularity of the tumor, but also to its vascular pattern. There is relatively little or diminished concentration of dye over the sites of large cysts.

Localization proved to be much more precise than with electroencephalog-

raphy or with pneumography, when verification was obtained at surgery or at autopsy.

The negative findings also proved to be 95 per cent accurate and were of equal importance in the differential diagnosis of space-occupying lesions from non-surgical lesions of the central nervous system, especially in those cases in which there was papilledema or Jacksonian epilepsy. Special technics of counting have been evolved so that the accuracy of localizing midline tumors, such as those of the pituitary, brainstem, or posterior fossa, is as good as localizing the more superficial cerebral neoplasms.

We believe that the radioactive di-iodo-fluorescein test is a simple, safe, painless, and reliable method for the localization and diagnosis of brain tumors, and one that should grow in value as increasingly more sensitive detection equipment and newer radiodyes become available.

## REFERENCES


1. Ashkenazy, M., LeRoy, G. V., Fields, T., and Davis, L. The detection of intracranial tumors by the use of di-iodo$^{131}$-fluorescein. *J. Lab. clin. Med.*, 1949, *34:* 1580–1581.
2. Boyland, E., and McClean, D. A factor in malignant tissues which increases the permeability of the dermis. *J. Path. Bact.*, 1935, *41:* 553–565.
3. Broman, T. Supravital analysis of disorders in the cerebral vascular permeability in man. *Acta med. scand.*, 1944, *118:* 79–83.
4. Brunschwig, A., Schmitz, R. L., and Clarke, T. H. Intravital staining of malignant neoplasms in man by Evans blue. *Arch. Path.*, 1940, *30:* 902–907.
5. Davis, L., Martin, J., Ashkenazy, M., LeRoy, G. V., and Fields, T. Radioactive diiodofluorescein in diagnosis and localization of central nervous system tumors. *J. Amer. med. Ass.*, 1950, *144:* 1424–1432.
6. Duran-Reynals, F. Studies on the localization of dyes and foreign proteins in normal and malignant tissues. *Amer. J. Cancer*, 1939, *35:* 98–107.
7. Fields, T., LeRoy, G. V., and Ashkenazy, M. External localization of brain tumors by means of radioactive di-iodo-fluorescein; medical physics aspects. In: *Third annual joint AIEE-IRE conference on electronics in nucleonics and medicine.* New York: American Institute of Electrical Engineers. (In press)
8. Gough, J. The structure of the blood vessels in cerebral tumours. *J. Path. Bact.*, 1940, *51:* 23–28.
9. Hardman, J. The angioarchitecture of the gliomata. *Brain*, 1940, *63:* 91–118.
10. LeRoy, G. V., Tweedy, W. R., and Ashkenazy, M. Radioactive di-iodo-fluorescein; the health physics aspects of its use for diagnostic studies. (To be published)
11. Ludford, R. J. The vital staining of normal and malignant cells.—II. The staining of malignant tumours with Trypan blue. *Proc. roy. Soc.*, 1929, *104:* 493–512.
12. Moore, G. E. Fluorescein as an agent in the differentiation of normal and malignant tissues. *Science*, 1947, *106:* 130–131.
13. Moore, G. E. Use of radioactive diiodofluorescein in the diagnosis and localization of brain tumors. *Science*, 1948, *107:* 569–571.
14. Moore, G. E., Hunter, S. W., and Hubbard, T. B. Clinical and experimental studies of fluorescein dyes with special reference to their use for the diagnosis of central nervous system tumors. *Ann. Surg.*, 1949, *130:* 637–642.
15. Moore, G. E., Peyton, W. T., French, L. A., and Walker, W. W. The clinical use of fluorescein in neurosurgery. The localization of brain tumors. *J. Neurosurg.*, 1948, *5:* 392–398.
16. Sahs, A. L., and Alexander, L. Vascular pattern of certain intracranial neoplasms. Studies with the benzidine stain. *Arch. Neurol. Psychiat., Chicago*, 1939, *42:* 44–66.
17. Seifter, J., Baeder, D. H., and Dervinis, A. Alteration in permeability of some membranes by hyaluronidase and inhibition of this effect by steroids. *Proc. Soc. exp. Biol., N. Y.*, 1949, *72:* 136–141.
18. Virchow, R. Die krankhaften Geschwülste. *Berlin: A. Hirschwald*, 1863–67, 3 vols. (see vol. 2, p. 141).

# CASE REPORTS

## A CASE REPORT AND SURVEY OF BRAIN TUMORS DURING THE NEONATAL PERIOD

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Brain tumors during the neonatal period are rare and usually are not recognized during life. We have recently encountered a cavernous hemangioma in the lateral ventricle of a 3-day-old infant.

This has led us to review the subject of brain tumors during this period.

### CASE REPORT

W. D., a 2-day-old male, was admitted to the University of California Hospital because of regurgitation of food since birth. The referring physician had placed some lipiodol into the esophagus and established the fact that this pathway was not patent. The fact that part of the radiopaque material was found in the respiratory tract led to the further assumption of a tracheo-esophageal fistula.

The child had 2 siblings living and well. The mother was 29 years old, the father 49. There was no family history of any disease. The pregnancy had not been unusual, and no difficulties had been encountered during delivery.

*Examination.* The infant weighed 2,580 gm., was 43 cm. in height, and had a head circumference of 34 cm. He was not dehydrated and appeared to be in a fairly satisfactory state of nutrition. His cry was somewhat hoarse, but the rest of the examination was not remarkable except for some mucoid discharge and droplets of lipiodol in the upper respiratory tract. The abdomen was moderately tympanitic. The fundi were not seen.

Routine laboratory studies were not remarkable. X-ray examination confirmed the entry diagnosis of atresia of the esophagus with a tracheo-esophageal fistula. Hemivertebra and other anomalies of structure at T7 and T8 were noted. There was partial fusion of T10–11, as well as L1–2–3.

*Operation.* On the day after admission, a retropleural exposure of the esophagus was carried out by Dr. H. B. Stephens. The proximal and distal portions were found to be separated by a distance of 5 cm. and sufficient mobilization could not be achieved to perform a direct anastomosis. The fistula between the trachea and distal portions of the esophagus was repaired and a gastrotomy was performed. The patient withstood the procedure fairly well.

*Course.* The patient's immediate postoperative course was smooth, although there was some edema of the lower portion of his body. Late in the 2nd day after surgery, his extremities suddenly became somewhat cyanotic, and respiration rather rapidly became stertorous and irregular. He expired quickly without responding to any further treatment.

*Autopsy.* Examination confirmed the operative observation of atresia of the esophagus with marked separation of the two segments. The tracheo-esophageal fistula had been successfully ligated, but there was some mediastinitis near the operative area. Multiple other anomalies were noted. There was a marked hypoplasia of the right kidney with a levoposition, and an anomalous right ureter. There was a Meckel's diverticulum, and an ectopic pancreas was attached to the pyloric ring. Bicuspid aortic and pulmonic valves were noted. There was also a large cavernous hemangioma of the choroid plexus in the right lateral ventricle with evidence of recent and "significant" hemorrhage (Fig. 1).

## DISCUSSION

Brain tumors during the neonatal period (birth to 60 days) are sufficiently rare and difficult to diagnose that they are almost invariably autopsy findings. In no case that we have been able to find was the diagnosis of tumor definitely established during life, although in 1 case (Cushing[8]) intracranial calcifications were noted, and in 1 case[11] there was a herniation of cerebral mass through the ruptured scalp. The possibility that certain cases of neonatal death may result from unsuspected intracranial neoplasm led us to review the literature.

We were able to find 13 recorded cases of intracranial tumors occurring during

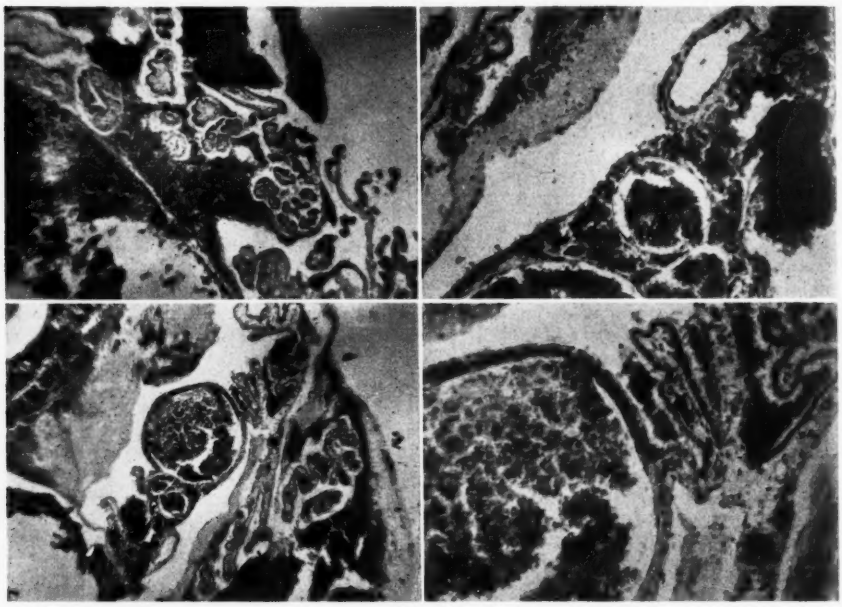

FIG. 1. Choroid plexus angioma in a 3-day-old infant. Hematoxylin and eosin stain.

this period of life. There were, in addition, 3 cases of tumors that became manifest shortly after the neonatal period and which probably were present though not recognized earlier. Reviewing these lesions reported in the literature brings out several aspects in which they differ from the general run of tumors in childhood, and they consequently warrant special attention. The reported cases are listed in Table 1.

The varying terminology used by different authors makes comparison of pathological types somewhat difficult, though it would appear that about half of these lesions were gliomas. Contrary to the situation that prevails with the general run of tumors in childhood,[4] most of the tumors in the neonatal period were supratentorial. It will be noted in Table 1 that there were 3 below and 9 above the tentorium, the location being undetermined in 1 case.

Unfortunately, a review of the available information with reference to these lesions does not yield any valuable clues for recognizing them more easily. Hydro-

cephalus was the most frequently encountered feature, but was not invariably present. It was noted, however, that in 4 of the patients the course of the hydrocephalus was unusually rapid—and this factor may be of some diagnostic importance. One patient had an increase in intracranial pressure sufficient to rupture the scalp. In 2 patients, congenitally present tumors caused so marked an increase in the size of the head that dystocia and other birth difficulties resulted. In 3 patients, including the 1 reported here, there were associated other anomalies. In 1 case there was a marked spinal fluid pleocytosis, which has been commented upon elsewhere[4] in association with intracranial tumors in childhood.

TABLE 1

*Reported cases of intracranial tumors occurring in neonatal period*

| Author | Age of Pt. | Tumor Type | Location | Comment |
|---|---|---|---|---|
| 1. Leibner[13] | 3 wks. | Medulloblastoma | Rt. cerebral hemisphere | Diagnosis unsuspected. Head+at birth. Conv. & cyanosis. |
| 2. Maier[15] | 6 wks. | Dermoid | Lat. ventricle | Hydrocephalic |
| 3. Abelin[1] (also cit. by Steffen[20]) | 6 wks. | Sarcoma | 4th ventricle | Hydrocephalic |
| 4. Saxer[19] | 7 wks. | Teratoma | 3rd ventricle | Head size+. Tumor attached to choroid plexus. |
| 5. Holt;[11] also reported by Wollstein and Bartlett[22] | 2 wks. | "Gliosarcoma" | Lt. cerebral hemisphere | Hydrocephalic. Scalp ruptured; cerebral hernia. Protein & cells in CSF. |
| 6. Lato[12] | 2 mos. | "Cystic blastoma" | Midbrain | |
| 7. Derman[9] | 1 mo. | Teratoma | Pineal region | Rapid+head size. |
| 8. Gross[10] | 2 mos. | Pinealoblastoma | Pineal region | Sudden+head size. Choroid plexicotomy. |
| 9. Russell and Ellis[18] | Birth | Atypical polar spongioblastoma | Lt. cerebral hemisphere | Hydrocephalic. Stillbirth. |
| 10. Cushing[8] | 2 mos. | Teratoma | Between lat. hemispheres | Rapid+head size. Calc. in x-ray. |
| 11. Baxter[3] | Birth | Teratoma | Undetermined | Caused dystocia. Head opened to permit birth. |
| 12. Canavan and Hemsath[6] | Birth | Ependymoma | 4th ventricle | Incidental finding. |
| 13. Alpers[2] | 5 wks. | "Resembles granule cells of cerebellum" ?Medulloblastoma | Iter | Other anomalies: myelomeningocele, cerebellar aplasia. |

The presence of these lesions during this very early period of life lends supportive evidence to the "embryonal rest" theory of their etiology.[14] The fact that 5 of them were of the dermoid or teratoid group is in keeping with this theory, in view of the fairly clear relationship between lesions of this sort and embryonal rests. The close association between arteriovenous anomalies and vascular tumors has been extensively commented upon elsewhere.[16]

Our patient differs from the majority of the group in that he did not have hydrocephalus. There were, however, multiple associated anomalies, and while there was ample other cause for death the pathologist was of the opinion that bleed-

ing from the angioma was the most important factor. As was true in most of the reported cases, the lesion was unsuspected during the patient's life.

In view of the well established association between the angiomatous lesions and congenital anomalies, it seems likely that when greater experience is accumulated with tumors in the neonatal period, a significant portion of them will be angiomata. In spite of the fact that the literature is liberally sprinkled with cases such as those belonging to the "Sturge-Weber syndrome" (which we assume to include congenitally present angiomas) we have been unable to find record of an intracranial angioma recognized in a patient as young as the one herein reported. While many such lesions are doubtless present at birth, and a certain number may be causes of neonatal death, the youngest patient that we have found previously reported was that of Ray,[17] a 2½-year-old boy. The circumstantial evidence that suggests that many of these lesions are present at birth makes it likely that as increased attention is paid to them, they may be reported in greater numbers.

In addition to the 14 tumors of the neonatal period that are summarized here, we have encountered in the literature 3 others (Braune,[5] Critchley,[7] and Van Wagenen[21]) occurring in young infants whose age brings them only slightly out of the neonatal period (the first 60 days of life) and which were doubtless present during this time even if not manifest.

## SUMMARY

A case of cavernous angioma of the choroid plexus of a 3-day-old infant is reported.

In a review of the literature of cases of brain tumor occurring during the neonatal period, we were able to find only 13 previous reports of such lesions.

The tumors of the neonatal period are more frequently supra- than infratentorial, and about half of those reported appear to have been gliomas.

Hydrocephalus appears to have been the only finding common to most of the cases reported in this period, and this was not invariably present. All of the cases reported showed a uniformly short course and a poor prognosis.

The presence of tumors during the neonatal period is regarded as supportive evidence for the "embryonal rest" theory of the genesis of certain intracranial neoplasms. The pathological nature of the lesions reported lends further support to this thesis.

## REFERENCES

1. Abelin, H. Klinische Mittheilungen. *J. Kinderkr.*, 1870, *55:* 83–132.
2. Alpers, B. J. Tumor of the iter and fourth ventricle associated with a meningo-myelocele and absence of the cerebellum in an infant of five weeks. *J. Mt. Sinai Hosp.*, 1942, *9:* 296–298.
3. Baxter, J. Foetal brain tumour as a cause of dystocia. *J. Obstet. Gynec.*, 1947, *54:* 380–381.
4. Boldrey, E. B., Naffziger, H. C., and Arnstein, L. H. Signs and symptoms of supratentorial brain tumors in childhood. *J. Pediat.*, 1950, *37:* 463–468.
5. Braune, B. Hirntumoren beim Säugling. *Arch. Kinderheilk.*, 1937, *112:* 193–202.
6. Canavan, M. M., and Hemsath, F. A. Glioma in the fourth ventricle of a prematurely born infant. *Arch. Neurol. Psychiat., Chicago*, 1931, *26:* 1234–1236.
7. Critchley, M. Brain tumours in children: their general symptomatology. *Brit. J. Child. Dis.* 1925, *22:* 251–264.
8. Cushing, H. Intracranial tumours. Notes upon a series of two thousand verified cases with surgical mortality percentages pertaining thereto. *Springfield, Ill.: Charles C Thomas*, 1932, xii, 150 pp. (see p. 102).
9. Derman, G. L. Zur Kenntnis der Teratome des Gehirns. *Virchows Arch.*, 1926, *259:* 767–772.
10. Gross, S. W. Tumors of the brain in infancy. Clinical and pathologic study. *Amer. J. Dis. Child.* 1934, *48:* 739–763.

11. Holt, L. E. Gliosarcoma in an infant of seven weeks, resembling hydrocephalus. *Amer. J. Dis. Child.*, 1917, *14:* 219–221.
12. Lato, M. Un caso di tumore cerebrale congenito in un lattante. *Clin. pediat., Bologna*, 1947, *29:* 177–180.
13. Leibner, I. W. Brain tumors in infancy. A report of seven cases. *Pediatrics*, 1948, *1:* 346–363.
14. MacPherson, D. J. Studien über den Bau and die Lokalisation der Gliome, mit besonderer Berücksichtigung ihres Missbildungscharakters. *Arb. neurol. Inst. Univ. Wien*, 1925, *27:* 123–155.
15. Maier, R. Combinirte Geschwulst im Grosshirn. *Virchows Arch.*, 1861, *20:* 536–541.
16. Olivecrona, H., and Riives, J. Arteriovenous aneurysms of the brain. Their diagnosis and treatment. *Arch. Neurol. Psychiat., Chicago*, 1948, *59:* 567–602.
17. Ray, B. S. Cerebral arteriovenous aneurysms. *Surg. Gynec. Obstet.*, 1941, *73:* 615–648.
18. Russell, D. S., and Ellis, R. W. B. Circumscribed cerebral tumours in young infants. *Arch. Dis. Childh.*, 1933, *8:* 329–342.
19. Saxer, F. Ein zum grössten Theil aus Derivaten der Medullarplatte bestehendes grosses Teratom im III. Ventrikel eines 7 wöchentlichen Kindes. *Beitr. path. Anat.*, 1896, *20:* 399–412.
20. Steffen, A. Die Krankheiten des Gehirns im Kindesalter. In: *Handbuch der Kinderkrankheiten.* C. Gerhardt, Ed. Tübingen: H. Laupp; 1880 *5*, pt. 1, 2nd div.: 207–712 (see pp. 560, 576).
21. Van Wagenen, W. P. Papillomas of the choroid plexus. Report of two cases, one with removal of tumor at operation and one with "seeding" of the tumor in the ventricular system. *Arch. Surg., Chicago*, 1930, *20:* 199–231.
22. Wollstein, M., and Bartlett, F. H. Brain tumors in young children. A clinical and pathologic study. *Amer. J. Dis. Child.*, 1923, *25:* 257–283.

# TWO-STAGE AUTOGRAFT FOR REPAIR OF EXTENSIVE DAMAGE TO SCIATIC NERVE

## REPORT OF CASE

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In November, 1947, two-stage autograft for the repair of extensive defects of median and ulnar nerves was described by Shelden, Pudenz and the present writer.[1] This consisted of a two-stage procedure in which the ulnar nerve was used as an autograft. Its principal technical advantage was the maintenance of blood supply in the graft at all times, according to the same principle that is used to maintain a blood supply in a pedicle skin graft. It was suggested in the original communication that extensive injury to the sciatic nerve might be repaired by use of the peroneal division as the source of the graft. The case to be described is one in which this type of graft was used. The graft apparently is functioning satisfactorily.

## REPORT OF CASE

On May 20, 1947, an 11-year-old boy was registered at the Mayo Clinic because of paralysis of the right sciatic nerve. He had been accidentally shot through the anterior aspect of the right thigh with a shotgun on Nov. 7, 1946. He had been unconscious for 3 or 4 hours as a result of profound loss of blood. There was immediate and complete paralysis of the sciatic nerve below the innervation of the hamstring and gluteus muscles. Sensory loss was complete. The wounds were packed and allowed to granulate. Many pellets had penetrated the leg and had left wounds of exit posteriorly.

On May 28, 1947, approximately 6 months after the injury, the sciatic nerve was explored. A long S-shaped incision was utilized which exposed the nerve in the posterior part of the thigh after the overlying skin and muscle scars had been excised. It was apparent that the sciatic nerve had been destroyed from just below the gluteal fold to just above the popliteal

fossa, a distance of 13 cm. in this patient (Fig. 1). The nerve ends could not be approximated. The popliteal fascia was divided. The incision was extended laterally around the buttocks. The gluteus maximus muscle was detached from the femur and was reflected medially. With the hip in extension and the leg in flexion, the nerve ends still could not be approximated. The posterior tibial and peroneal divisions of the proximal part of the sciatic nerve were then separated distally and near the sciatic notch. The branches to the hamstring muscles of the posterior tibial division of the sciatic nerve were not injured. The peroneal division was tran-

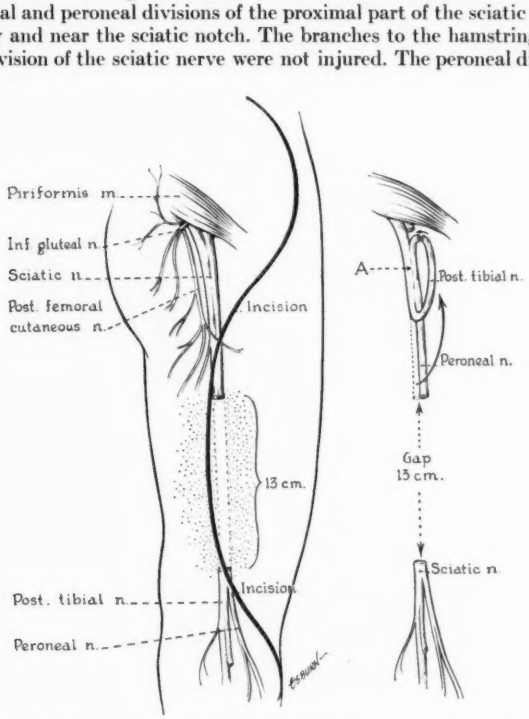


FIG. 1. Extent of the defect in the right sciatic nerve of a boy 11 years old. The incision employed for exposure is depicted by the heavy line, and the first stage in the grafting procedure is outlined. The posterior tibial division was anastomosed to the peroneal division in such a manner that the centrifugal direction of the nerve fasciculi was maintained. The blood supply to the graft was maintained by reason of the fact that the two divisions of the proximal portion of the sciatic nerve were not completely separated.

sected at the notch. The proximal end of the posterior tibial nerve was then sutured to the peroneal graft at the site at which it had been divided at the sciatic notch (Fig. 1). Great care was taken not to disturb the intact blood supply of the peroneal graft. Arterial silk sutures were used for the anastomosis. All the nerve elements of the sciatic nerve were then protected with polythene membrane to facilitate subsequent surgical procedures.

The patient returned to the clinic on Oct. 7, 1947. A draining sinus had developed in the posterior part of the thigh. On Oct. 11, 1947, the sinus tract was removed, along with the polythene membrane which apparently was acting as a foreign body.

On Nov. 26, 1947, one year after the injury, the nerve graft was completed. The previous incision was opened. The peroneal graft was dissected from the tibial portion of the nerve (Fig. 2). Again, great care was taken to preserve the motor branches to the hamstring muscles. The graft was freed in its entirety. It lacked approximately 5 to 7 cm. of reaching the distal

segment of the sciatic nerve. Therefore, it was necessary to hyperextend the thigh and flex the leg. In this position we were able to bring the graft in approximation with the distal portion of the sciatic nerve, just above the popliteal fossa (Fig. 2). The graft was purposely sutured to the entire nerve, and not merely to the posterior tibial division of it. Technically, this was easier; moreover, we thought that we might consequently reinnervate, to some degree at least, both divisions of the sciatic nerve with posterior tibial fasciculi. The anastomosis was accomplished with arterial silk sutures. The skin was closed with catgut sutures and a spica cast was applied to maintain the hip, leg and ankle in the proper position (Fig. 3).

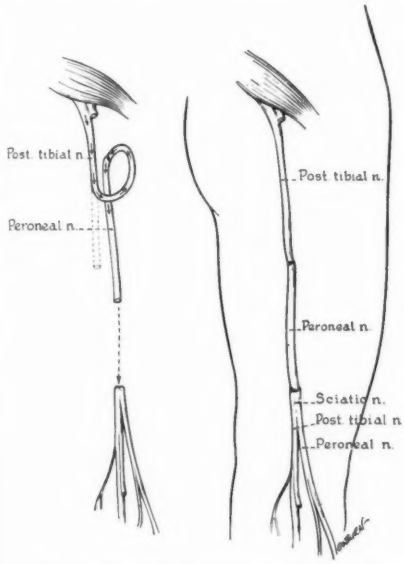


FIG. 2. Transfer of the peroneal division as a graft, and anastomosis of it to the distal portion of the sciatic nerve. The result was that tibial fasciculi travel through the peroneal graft into both terminal divisions of the sciatic nerve.

FIG. 3. Type of cast utilized for maintenance relaxation of the sciatic nerve and graft during the postoperative period.

The cast was removed 6 weeks after operation. During the entire course of his disability the patient received some form of physiotherapy. He was dismissed on Jan. 27, 1948, with a prescription for physiotherapy to be continued at his home. The leg had been allowed to straighten itself gradually without mechanical devices. At the time of dismissal the boy's leg could be fully extended. The foot drop was counteracted by a brace.

In a letter received in December, 1949, the patient stated "I can feel my leg down to my ankle and I think I am getting a bit of feeling in my foot." In another note in February, 1950, he stated that he was getting feeling on the bottom of his foot and that he could make his ankle move a little. Because of the rather encouraging reports from this boy, Dr. Frank Turnbull of Vancouver, B. C., was asked to check the actual status of the sciatic nerve. We are indebted to him for his reply, a portion of which he has permitted us to quote: "I examined him on May 18 [1950]. There is no doubt that he has had some return of function. . . . He has moderate power in the gastrocnemius and weak power in the soleus. It is difficult to judge this because of very limited range of movement of the foot but the contraction of these

muscles is firm . . . . He can appreciate pinprick sensation at about the center of each malleolus laterally and medially and over the dorsum of the ankle. The only sensation that I could detect in the foot is vague appreciation of firm pinch of the pad of the big and second toes. The pinch would cause discomfort above the ankle. The skin of the foot is dry and shiny but entirely intact. He has no trouble with ulcers on the foot and reports that he has been playing sports, including softball and basketball."


## SUMMARY

A patient with an extensive injury to the right sciatic nerve was treated successfully by a two-stage procedure in which the peroneal division was utilized as an autogenous nerve graft.

The surgical technic described in detail had been suggested in a previous communication.


## REFERENCE


1. Shelden, C. H., Pudenz, R. H., and MacCarty, C. S. Two-stage autograft for repair of extensive median and ulnar nerve defects. *J. Neurosurg.*, 1947, *4*: 492–496.


# BRAIN TUMOUR WITH NORMAL AIR ENCEPHALOGRAPHY AND ARTERIOGRAPHY

## REPORT OF AN UNUSUAL CASE


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That a cerebral tumour may produce gross hemiparesis, hemi-hypaesthesia, and dysphasia and yet produce no alteration of the ventricular system or of the carotid arteriogram seems rather surprising. As an unusual example of a problem which must be faced by all who endeavour to treat neurological disease, the following case is reported.

## CASE REPORT

National Hosp. No. 19432. E. P., a married woman of 62 years, was admitted on Oct. 21, 1949 under the care of Dr. E. A. Carmichael. She had been well up to 1 year before admission when she seemed to be easily tired and suffered from a series of mild upper respiratory infections from which she never recovered to normal health. Five months before admission, slight weakness and clumsiness of the right arm were noticed, followed by weakness of the right leg 2 weeks later. This gradually progressed and for the last 14 days she had been completely paralysed in the right arm and barely able to walk on the right leg. Her walking was slow and she dragged the leg after her and tended to swing it outwards. The left arm and left leg were unaffected.

For the last 6 weeks she had had a disorder of speech. She described her disability as difficulty in finding the word that she wished to use. She maintained that she was well aware of what she wanted to say, that she understood perfectly what was said to her and what she read. She felt that if it were not for her paralysis she would be able to write. Although this speech disorder fluctuated considerably it gradually progressed. On admission her speech was understandable although the impairment was obvious.

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Two months before the onset of weakness, she had suffered from headaches approximately once a week. These were generalised dull aching pains accompanied by injection of her eyes. They were not a prominent feature of her illness and disappeared after a few months. She had lost about 28 lbs. during the last year; she said that even though she often felt hungry, at the sight of food, she felt that she could not eat.

There was no family history of nervous or mental disease.

*Examination.* She was co-operative and there did not appear to be any gross intellectual deterioration. B.P. was 190/90, P. 72, T. 98.4° F. There was a dysphasia which was almost entirely expressive. On rare occasions she was able to produce an entire sentence without error, but for the most part she was hesitant, frequently using words which obviously did not express exactly what she wanted to say. No jargon words were heard. Her ability to understand the spoken word, to understand written commands, and to read out passages was good. She made a few errors in attempting to name objects, but ability to write could not be tested owing to her hemiplegia. No left-right disorientation could be demonstrated but there appeared to be a finger agnosia. There was no papilloedema or other abnormal sign in the cranial nerves.

The gait was hemiplegic; the right shoulder lower than the left, the right arm held immobile in a position of adduction and flexion, the right foot inverted with a slight foot drop. The leg was dragged stiffly behind her and circumducted, with the toes scraping the ground. She was unable to maintain a posture of the right upper or lower limbs. There was considerable reduction of power in the right arm and leg, worse in the arm than the leg and most marked in the flexors and extensors of the fingers. Owing to this weakness, co-ordinated movements were not possible on the right side. Slight spasticity was present in the flexors and pronators of the right arm but the right leg was not spastic. Deep reflexes were normal in the upper extremities and in the left lower extremity. The knee jerk on the right was hyperactive but the ankle jerk on that side could not be elicited. Abdominal reflexes were absent. The left plantar response was flexor; the right was absent. There was slight impairment of all forms of cutaneous sensibility and vibration on the right side of the body, with marked reduction in two-point discrimination and stereognosis. There was gross loss of sense of position in the right hand and right foot. There was a fairly severe degree of varicosity of the veins of both legs.

*Laboratory Data* (Dr. J. M. Cumings). Hb. 104 per cent; W.B.C. 6,800/c.mm.; 72 per cent polymorphonuclears; 26 per cent lymphocytes; 2 per cent eosinophils; platelets 250,000/c.mm. The lumbar CSF was clear and colourless with an initial pressure of 130 mm.; cell count normal, protein 40 mg. per cent, Pandy and Nonne Appelt tests negative, Lange normal.

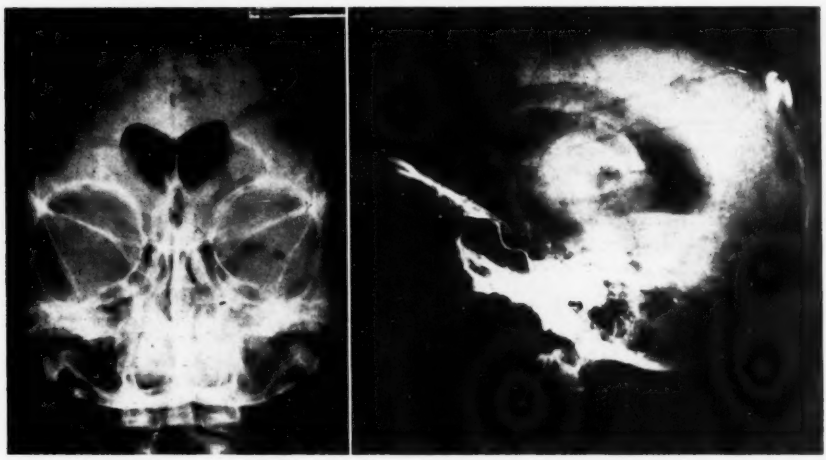
*EEG Report* of October 11 (Dr. W. A. Cobb) indicated "a widespread lesion in the left hemisphere resulting in abolition of frontal fast activity and release of alpha activity, as well as the more direct effects causing a slow wave response. It is, I think, consistent with a cerebral neoplasm though rather atypical."

*Roentgenographic Findings* (Dr. D. Sutton). Films of skull and chest normal. Fluoroscopic examination of upper gastro-intestinal tract following ingestion of barium revealed no abnormality. On Oct. 25, 1949 left percutaneous cerebral arteriography was performed. "There was fair filling of the internal carotid artery, including the posterior cerebral artery. The anterior cerebral artery lay in the midline and the vessels generally appeared normal in position and distribution. Conclusions: no lesion detected." On Nov. 11, 1949 a lumbar air encephalogram was done. There was "good filling of the ventricular system. The septum pellucidum, 3rd and 4th ventricles lay in the midline. The lateral ventricles were on the large side of normal, but were symmetrical and showed no deformity" (Figs. 1 and 2).

*Course.* There was no change in her condition, and on November 15 she was transferred to a convalescent home. Two weeks later she suddenly lost consciousness and was re-admitted to the National Hospital. She was in status epilepticus with attacks involving the right face, arm and leg occurring at intervals of 5–6 min. and lasting 30 sec. There appeared to be no recovery of consciousness between the attacks. Intravenous pentothal sodium was administered and the attacks ceased. She recovered consciousness 30 min. later and was found to have gross right-sided hemiplegia and to be almost completely aphasic. Although there were no further seizures, the paralysis and dysphasia failed to improve. On the morning of Dec. 4,

1949 she could not be aroused; her lips were cyanotic and there was froth at the corners of her mouth. The right pupil was slightly larger than the left but both reacted briskly to light. Corneal reflexes were brisk but no other response could be obtained to painful stimuli. R. 25; B.P. 170/96. Both arms and legs were completely flaccid. No plantar response and no abdominal reflexes could be obtained; all deep reflexes were absent. There was no neck stiffness and no Kernig sign. Blood sugar, blood urea and urine analysis were normal. Lumbar puncture showed clear and colourless fluid under a pressure of 160 mm. The respiratory rate gradually increased and the temperature rose, and without regaining consciousness the patient died on Dec. 6, 1949, 2 days after the onset of this acute episode.

*Necropsy.* Skull, air sinuses, dura, venous sinuses, basal vessels and leptomeninges were healthy. The brain showed neither gross swelling nor atrophy. The gyri of the anterior oper-



FIGS. 1 and 2. Anteroposterior and lateral views of the air encephalogram.

culum of the insula on the right side were slightly broadened and firm in consistence. There was very slight temporal herniation, more marked on the right side.

On section there was a swelling and pallor of the anterior corpus striatum, lentiform nucleus and thalamus on the left side, with a cortical and subcortical replacement by firm pale tissue of most of the anterior part of the floor of the insula on the left side. The left cerebral peduncle was broader than the right but there was no obvious abnormality in the pons or medulla. The ventricles were not dilated. The body of the left lateral ventricle was very slightly narrowed and its lateral angle was 2 mm. further from the midline than the right (Fig. 3C).

*Microscopically* the tumour was found to be more extensive than was expected from the macroscopical appearances. The most active part of the tumour lay in the anterior part of the left insula. Here it replaced both grey and white matter and was composed of closely packed glial cells with rounded, ovoid, reniform or elongated nuclei, often in mitosis, and but little cytoplasm. Glial fibres were rare. Swollen-bodied astrocytes were occasionally included in the tumour. Capillaries showed endothelial hyperplasia and occasional foci of necrosis were bordered by radially arranged tumour cells. The appearances here were those of a glioblastoma multiforme (Kernohan[2] type IV astrocytoma).

From this region the tumour spread widely but without the nerve cell and myelin destruction seen in the most active part. It extended *deeply* to involve the left caudate and lent-

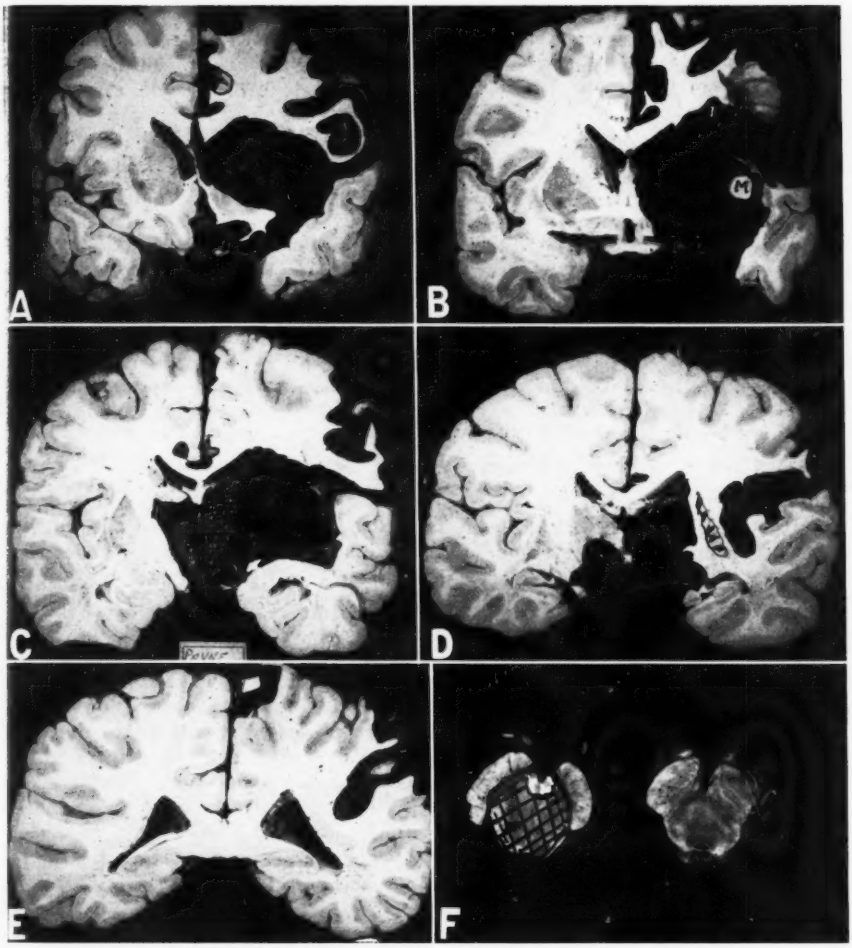



FIG. 3. Coronal sections of the brain viewed from the front. (A) Anterior to the optic chiasm; (B) at the optic chiasm; (C) through the mammillary bodies; (D) through the red nuclei; (E) through the splenium of the corpus callosum; (F) through the mid-brain (*left*) and at the junction of the mid-brain and pons. The darkened areas show the extent of the tumour and "M" marks the site of its maximum activity.

form nuclei, the amygdaloid nucleus (and adjacent cortex), the left thalamus and posterior hypothalamus, the internal capsule, the lateral geniculate body. It had crossed the midline to involve the right posterior hypothalamus and the inferior part of the thalamus. Downward spread from the basal structures involved both red nuclei and subthalamic nuclei, the tegmentum of the upper midbrain and the superior corpora quadrigemina.

It extended *superficially* and widely in the cortex and immediate subcortex. All the floor and the frontal and parietal opercula of the insula were involved. Thence it extended supe-

riorly in a broad band, in the posterior frontal and anterior parietal regions, to the superio margin of the hemisphere and down the medial aspect to the inferior limit of the gyrus cingul From this major band of cortical involvement minor extensions passed backwards toward the middle part of the convexity of the occipital lobe in its anterior part. Another extensio passed forwards to involve those portions of the supraorbital and medial frontal cortex tha lay superficial to the anterior corpus striatum. Above the corpus callosum at the coronal leve of the corpora mammillaria there was involvement of the indusium griseum.

In these deep basal regions and in the widespread cortical involvement the neoplasti change was different from that seen in the floor of the insula. In the deep basal regions i varied in activity from place to place, being more active in the thalamus than in the corpus striatum. In some regions nerve cells did appear to have been destroyed, in others not. Not only were there fairly numerous elongated abnormal glial cells but also there was a great increase in swollen-bodied and glial fibre-forming astrocytes. Within the internal capsule there were elongated tumour cells and swollen-bodied astrocytes in small numbers. The infiltration was less marked in the midbrain.

In the involved cortex, overlying the apparently intact deep white matter of the frontoparietal region, there was infiltration of all layers by abnormal glial nuclei with very little cytoplasm, elongated in shape and orientated radially and by fibre-forming astrocytes. Although nerve cell loss was only slight, several neurons showed satellitosis by glial or tumour cell nuclei.

## COMMENT

It is well recognised that although the history of a patient's disease may suggest that he has an intracranial tumour, air studies may show no abnormality. This has been stated by Poppen and Peacher[6] in their report of 10 such cases, and also by Merritt and Brenner[3] who recorded the findings in 3 similar patients. The study by Pennybacker and Meadows[5] has the additional advantage of postmortem studies on the 4 patients whom they followed. Three of these had normal air studies $5\frac{1}{2}$ months, 5 months and 5 days respectively before death; but at autopsy there was a shift of the septum pellucidum, though it was slight, in the third case. The ventriculogram of the fourth patient, performed 3 months before sudden death during a convulsion, was normal and although no mention of the ventricles is made in the necropsy report one assumes that there was no displacement since the tumour was a small one near the surface of the parietal lobe and not associated with oedema or haemorrhage.

None of the patients mentioned in the above three papers was investigated by arteriography. As a single ancillary investigation this method also has its limitations in helping to confirm the clinical diagnosis of cerebral tumour. Attention has recently been drawn to its fallibility by Culbreth, Walker and Curry[1] who stated that: "In supratentorial tumours carotid angiography may fail to show tumours of the basal ganglia and midline structures, the inferior temporal region and the occipital region. For the demonstration of such tumours ventriculography is preferable to angiography."

Air studies or arteriography alone may be normal in the early stages of cerebral gliomata owing mainly to the size and site of the tumour. Repetition of the test at a later date will give positive evidence of abnormality in many cases. In some cases, however, no such abnormal findings are revealed even in the late stages. We consider our case to be unique in having both normal findings up to 6 weeks before death, and at necropsy an undisplaced ventricular system in the presence of a glioma that had produced gross hemiparesis, hemi-hypaesthesia and dysphasia. Although in this patient there was involvement of the central grey matter, pronounced in

volvement of the cortex distinguished it from the cases of thalamic tumour described by Nevin.[4] The pure intracortical type of spread of this tumour is one of the modes of growth of a glioma named by Scherer[7] a secondary structure. The extensive infiltration of the cortical grey matter produced widespread dysfunction with little distortion of the gross appearance of the cerebrum, and this is the reason why such profound disability could be present with normal air studies and arteriogram. This case emphasizes the fact that a glioma may kill its host without producing pathological changes demonstrable by the ancillary methods of investigation in use today. The most constant diagnostic feature in the natural history of such tumours remains their relentless progressive course.

SUMMARY

There is reported a case of brain tumour which produced hemiparesis, hemi-hypaesthesia and dysphasia in which carotid arteriography and air encephalography disclosed no abnormality and which at necropsy showed no displacement of the ventricular system.

The authors are indebted to Dr. E. Arnold Carmichael for permission to report the clinical aspects of this case.

REFERENCES

1. Culbreth, G. G., Walker, A. E., and Curry, R. W. Cerebral angiography in "brain tumor suspects." *J. Neurosurg.*, 1950, *7:* 127–138.
2. Kernohan, J. W., Mabon, R. F., Svien, H. J., and Adson, A. W. A simplified classification of the gliomas. *Proc. Mayo Clin.*, 1949, *24:* 71–75.
3. Merritt, H. H., and Brenner, C. Normal air encephalograms in patients with convulsive seizures and tumor of the brain. *New Engl. J. Med.*, 1944, *230:* 224–225.
4. Nevin, S. Thalamic hypertrophy or gliomatosis of the optic thalamus. *J. Neurol. Psychiat.*, 1938, n.s. *1:* 342–358.
5. Pennybacker, J., and Meadows, S. P. Normal ventriculograms in tumours of the cerebral hemispheres. *Lancet*, 1938, *1:* 186–190.
6. Poppen, J. L., and Peacher, W. G. Brain tumors in the presence of normal air studies. *Surg. Clin. N. Amer.*, June 1943, *23:* 801–813.
7. Scherer, H. J. Étude sur les gliomes. *Bull. Ass. franç. Cancer*, 1936, *25:* 451–469.

## TORULA GRANULOMA OF THE CERVICAL SPINAL CORD*

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In their recent paper on the infection of the central nervous system by the *Cryptococcus hominis*, or *Torula histolytica*, Carton and Mount[3] presented an exhaustive review of the literature. They found only 10 instances in which either the spinal cord or its membranes showed involvement by Torula. In most of these cases the infection was widespread, also affecting the brain or its meninges. In only 3 instances was the infection confined to the spinal cord, the cauda equina or their

* Read before the Neurological Section of the Academia de Ciencias Médicas de Cataluna, April 17, 1950.

coverings. Of these 3 cases, 1 presented no clinical symptoms of involvement of the spinal cord (Freeman[5]); in 1 the vertebral column and the thoracic cavity were also invaded (Heinrichs[11]); and only in the case reported by Carton and Mount were the lesions confined to the neural structures with the expected neurological symptoms. In their case the granuloma involved the roots of the cauda equina so extensively that no attempt at its removal was made. This conservative attitude was further dictated by their knowledge of the etiological agent. Mosberg and Arnold,[14] in a review of the literature of torulosis of the central nervous system since 1946 (172 cases), found another instance of involvement of the spinal cord (and of the brain and kidney) which was reported by Jones and Klinck.[12]

In the case to be reported here the granuloma involved the cervical spinal cord and produced the typical symptoms of compression of that structure, without any signs of meningeal irritation. A diagnosis of a tumor of the spinal cord was made, the patient was operated upon and the extramedullary mass was removed. Its true nature was not recognized until the microscopical studies were made. To our knowledge this is the first reported case of human infection by *Torula histolytica* in Spain.

## CASE REPORT

*#P-4304.* Maria-Dolores P.U., an 8-year-old white girl from Tarrasa, Catalonia, Spain was first seen by us in consultation with Dr. F. Duran and Dr. Claveria on Nov. 3, 1949. She was the eldest of 6 healthy children. Her birth and subsequent development had been uneventful until the present illness.

In August 1949 she was first taken ill with a severe pain in the back of her neck which occasionally radiated into the right arm. The pain was most severe on arising in the morning. It was aggravated by exertion. It gradually increased in frequency and in severity. On Sept. 12 the spinous process of the 6th cervical vertebra was found to be tender and the muscles of the back of the neck were strongly contracted. Roentgenograms of the cervical spine were negative. The pains lessened when the neck was immobilized in a plaster cast, but a progressive paralysis of the upper extremities developed in the next 8 days. During the following week the lower extremities became spastic and paralyzed and were the seat of painful involuntary spasms. The upper extremities were hypotonic. She was constipated and had occasional urinary incontinence. She was afebrile throughout her illness.

*Examination.* The child was well-developed for her age, but very undernourished. T. was normal. She was quite uncooperative, crying and complaining whenever she was touched. There were almost continuous painful involuntary contractions of her legs. There was a complete lack of voluntary power in all extremities (Fig. 1). The upper extremities were hypotonic and markedly atrophic, particularly distally. She complained bitterly whenever her arms were moved. The biceps reflexes bilaterally and the stylo-radial and pronator-ulnaris reflexes on the right were abolished. The triceps reflexes, and the stylo-radial and pronator-ulnaris reflexes on the left were present but very weak. There was complete paralysis of the lower extremities with marked spasticity and hyperactive tendon reflexes, more marked on the right. Ankle clonus and Babinski's sign were present bilaterally. There was some difficulty with respiration but the diaphragm seemed unaffected.

Sensory examination was far from satisfactory but there appeared to be a zone of hyperesthesia just above the C5 dermatome. From C5 to T1 pain and temperature sensibility seemed to be decreased; while below that level they were lost. Tactile sensibility seemed to be preserved everywhere. Position sense was impaired in the toes.

The cranial nerves were intact.

X-rays of the cervical spine revealed some erosion of the pedicles and widening of the spinal canal from C4 to C6 (Fig. 2). The vertebral bodies and the intervertebral discs appeared normal.

FIG. 1. Photograph of patient taken on the 4th postoperative day.

Urinalysis and blood count were normal. Sedimentation rate was 19 mm. in the 1st hr., 40 mm. in the 2nd, and 105 mm. in 24 hrs. Katz index was 19.50.

*Diagnosis:* Tumor of the cervical spinal cord.

*Operation*, Nov. 7, 1949. The laminae of all of the cervical vertebrae and a small portion of the occipital bone were removed. The epidural fat formed a thickened firm sleeve of increased vascularity about the dural sac (Fig. 3 A, B, C). The dura mater was under great tension. When it was opened a greyish extramedullary mass was exposed (Fig. 3 C). This tumor was firmly adherent to the dura mater but was only loosely attached to the spinal cord (Fig. 3 C, D). It lay posterior to the cord, which it completely covered and severely compressed (Fig. 3 E, F, G). The mass was separated from the dura mater by sharp dissection but was readily separated from the spinal cord. Laterally it was adherent to a dentate ligament and seemed to receive most of its blood supply at that point (Fig. 3 G), although a few small vessels passed directly to the tumor from the surface of the spinal cord. The inferior margin of the tumor lay about 2 cm. above the lower end of the cervical spinal canal while the upper end lay in the cisterna magna. It was not adherent to the medulla oblongata or the cerebellum. The tumor was removed *en bloc*. The dura mater was closed tightly and the other soft tissues were closed in layers as usual.

*Postoperative Course.* Shortly after operation she had a moderate rise in T. to 38.5°C. and temporary respiratory embarrassment. Penicillin was given in doses of 100,000 units every 3 hrs. until a total of 7,000,000 units had been administered. Pain began to lessen in 24 hrs. and 5 days after operation she began to regain control over the paralyzed muscles.

FIG. 2. Roentgenogram of cervical and dorsal spine. Note widening of the canal and erosion of the pedicles. The dark shadows on the left are artefacts (buttons).

Her improvement continued steadily but slowly, and she was discharged on Nov. 26, 1949 Sensation was practically normal and her strength much improved. However, she could not flex or extend her fingers completely. She could bend her elbows but she could not extend them without help. Movement of the legs was possible only with considerable difficulty. The involuntary painful spasms of the legs had disappeared but there was still considerable spasticity

When seen again on Feb. 1, 1950 she was able to walk slowly and somewhat unsteadily, to write, and to play the piano. The spasticity of her legs had largely disappeared. The tendon

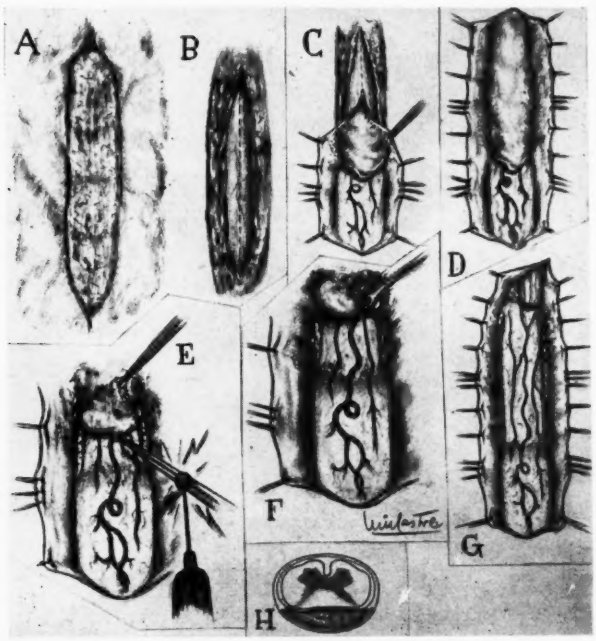


FIG. 3. Operative sketch. (A, B) Thickening of epidural tissue. (C, D) Appearance of the granuloma after opening the dura. (E, F) Two stages of the removal. (G) Appearance of medulla oblongata and spinal cord after removal of the granuloma. Note the two lateral bands to which the tumor was attached. (H) Schematic reconstruction showing situation of the granuloma and its relations to spinal cord and its meninges.

reflexes were still sluggish in the upper extremities and lively in the lower. Babinski's sign could not be elicited. She had gained 5 kg. (11 lbs.) in weight (Fig. 4). By July 6, 1950 she had completely recovered and was leading a normal life.

*Pathological Findings.* The mass removed at operation was greyish-white and firm in consistency. It was the size of a walnut (Fig. 5). Microscopically it was found to be composed of chronic inflammatory tissue with abundant giant cells, a few epithelioid cells and leucocytes, most of which were lymphocytes (Fig. 6). In some places there were noted the beginnings of follicular formations with a central giant cell surrounded by lymphocytes and epithelioid cells. In the cytoplasm of some of the giant cells were spherical bodies 10$\mu$ in diameter. These bodies resembled degenerated lymphocytes. They had a central part of nuclear appearance, which stained readily with hematoxylin and which was surrounded by a thick refringent cap-

FIG. 4. The patient 3 months after operation.

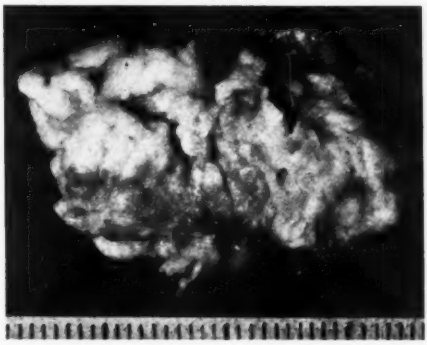

FIG. 5. Photograph of gross specimen removed at operation. (Scale in cm.)

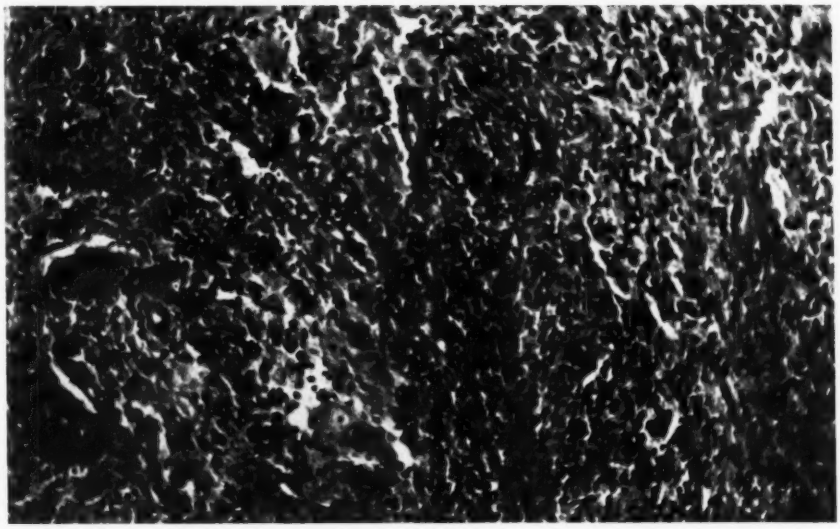

FIG. 6. General appearance of the granuloma under low magnification. Note the large number of giant cells scattered in the tissue (H. and E.).

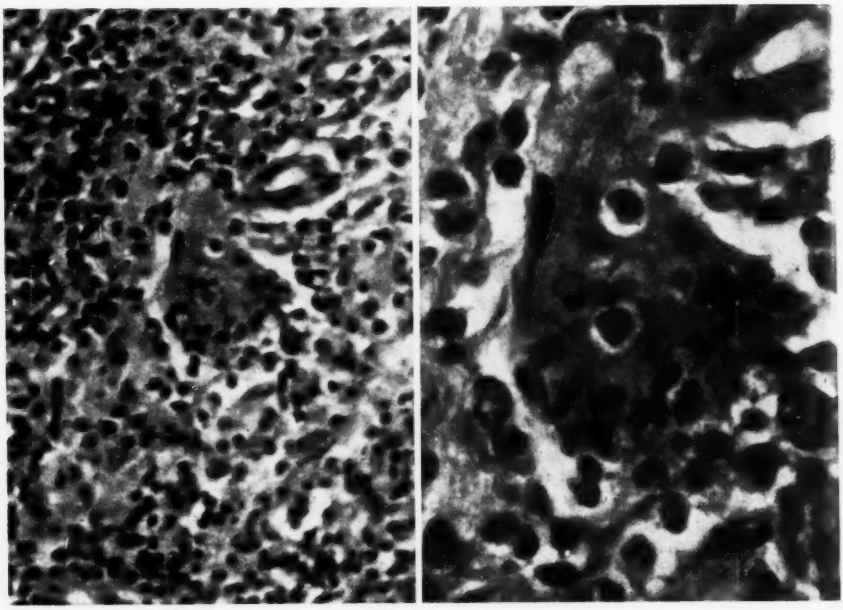

FIG. 7. *Left*, a giant cell containing two torula conidia. *Right*, the same cell under higher magnification (H. and E.).

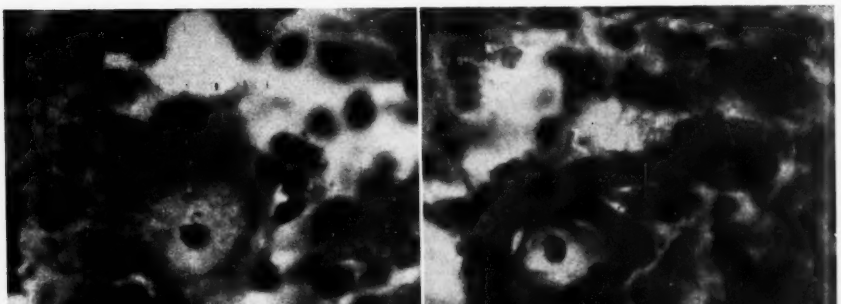

FIG. 8. Giant cells containing torula bodies seen under high magnification. Note the large hyaline capsules of these torula cells (H. and E.).

sule of gelatinous appearance (Fig. 7). The capsule was colorless, both in hematoxylin-eosin preparations and in sections impregnated with silver (Fig. 8). These bodies stained violet with Gram's method. The capsules varied in thickness and the spherical bodies ranged from 5 to 15$\mu$ in diameter. There were a few spherical bodies outside of giant cells, free in the tissues (Fig. 9). A few were seen in the perivascular spaces and even within the blood vessels. No endospores could be found. The blood vessels within this granuloma were mostly capillaries and arterioles. Most of them were surrounded by polymorphonuclear leucocytes, eosinophiles and lymphocytes. A rich network of reticulin radiated from the walls of the blood vessels.

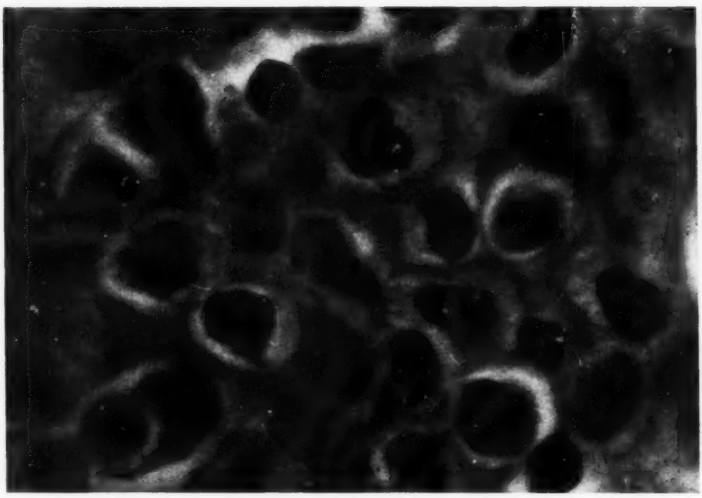

FIG. 9. Yeast-cells, lying free in the tissue. Note their resemblance to degenerated lymphocytes (H. and E.).

As the tumor had been promptly fixed in formalin, cultures and inoculations into laboratory animals were not possible. Nevertheless it seemed obvious that the spherical bodies were the causative agents of mycotic type. They had the typical appearance of yeast-cells and were thought to be *Torula histolytica*.

## DISCUSSION

Blastomycosis of the central nervous system has been rarely recognized in Spain. The only case previously reported was one of an obscure meningitis in which the spinal fluid contained some fungus-like cells which failed to grow on culture media. No pathological examination was made (Barraquer[1]).

Infection of the nervous system with *Torula histolytica* usually produces a rather widespread meningo-encephalitis, with a severe granulomatous reaction in the leptomeninx.[5,6,8,10,17] Sometimes the lesions may be more limited and localized in the brain, giving rise to minute cysts, so-called "soap suds" cysts,[6] with little or no alteration of the leptomeninx. These lesions can simulate a brain tumor.[3,13,18,20]

Torula granuloma limited to the spinal cord has been reported only once before (Carton and Mount[3]), and that very recently. On the other hand, Rand[16] has reported 2 cases of coccidioidal granuloma of the spinal cord. The macroscopic findings

in his cases were very similar to those reported here (Fig. 10). We, therefore, at first thought that we were dealing with such an infection and Verbiest,[19] who saw our patient and who had had a previous experience with a coccidioidal granuloma of the spinal canal, was of the same opinion. However, the cells were smaller than those found in coccidioidal infections; they had a typical yeast-like appearance, there were no endospores; and the thick hyaline capsule was typical of Torula.

The clinical course has been most gratifying. Seven months after removal of the granuloma the patient is free of symptoms and apparently cured. Most cases of Torula infection have terminated fatally in a few weeks to years, regardless of what form of treatment, medical or surgical, was used. What part the penicillin played in the recovery of our patient is undetermined.

FIG. 10. Reproduction of Rand's case[16] of coccidioidal granuloma of the spinal cord.

Green[9] concluded that sodium iodide, sodium salicylate and tartrate, magnesium sulphate, potassium tartrate, colloidal silver, thymol, quinine and gentian violet are all completely ineffective. Acriflavine, which is active *in vitro*, failed in one case treated by Warvi and Rawson.[21] The same was true of acti-dione, alkalosis, sulphonamides, streptomycin and aureomycin. The reports concerning penicillin have been contradictory. Fisher,[4] and Krainer *et al.*[13] found it ineffective *in vitro*, and Gifford and Hullinghorst[7] *in vivo*. On the other hand, Goldberg,[8] and O'Neill, Newcomb and Nielsen[15] reported beneficial results in their cases.

Freeman[6] has pointed out the variable virulence of different varieties of Torula, and the organism present in our case may have been one of lesser virulence. However, the cells present in our case were of the smaller size and Freeman points out that these are usually the more virulent. In any case it is obvious that the surgical removal of the granuloma with relief of the severe compression of the spinal cord was quite effective. It is possible that a similar decompression might have been effective in the case of Carton and Mount,[3] but knowing its nature, they elected not to remove the lesion. Bucy and Oberhill[2] had a successful experience similar to ours with another granuloma of the spinal cord of different etiology. We are of the opinion that a radical operation would be indicated in any case similar to that herein reported.

## SUMMARY

An extensive granuloma of the cervical spinal cord in a child 8 years old is reported. The symptoms were those of compression of the spinal cord. The granuloma was removed surgically and the child, who had a severe quadriparesis before the operation, recovered completely. Study of the surgical specimen indicated that the causative organism was the *Torula histolytica*. The authors stress the rarity of the case and advocate surgical extirpation of the granuloma in all similar cases.

We should like to acknowledge our gratitude to Dr. L. A. Mount and to Dr. R. E. Green for the valuable information they have provided and for making available to us the manuscripts of their papers before publication.

REFERENCES

1. Barraquer, L. Micosis nerviosa. *Monde méd.*, 1947, *57:* 79–84.
2. Bucy, P. C., and Oberhill, H. R. Intradural spinal granulomas. *J. Neurosurg.*, 1950, *7:* 1–12.
3. Carton, C. A., and Mount, L. A. Neurosurgical aspects of cryptococcosis. *J. Neurosurg.*, 1951, *8:* 143–156.
4. Fisher, A. M. Cited by Green.[9]
5. Freeman, W. Torula infection of the central nervous system. *J. Psychol. Neurol., Lpz.*, 1931, *43:* 236–345.
6. Freeman, W. Neuropathology. The anatomical foundation of nervous diseases. *Philadelphia: W. B. Saunders Co.*, 1933, 349 pp.
7. Gifford, H., and Hullinghorst, R. L. Streptomycin in cryptococcosis. *Calif. Med.*, 1948, *69:* 279–282.
8. Goldberg, F. A. Torula meningitis. *Memphis med. J.*, 1948, *23:* 129–130.
9. Green, R. E. Torula (*Cryptococcus hominis*) meningo-encephalitis treated by alkalinization and acti-dione. Case report. *Arch. intern. Med.* (In press)
10. Hassin, G. B. Histopathology of the peripheral and central nervous systems. *Baltimore: Wm. Wood & Co.*, 1933, xiii, 491 pp.
11. Heinrichs, H. Beitrag zur Pathologie der Blastomykosen. *Zbl. allg. Path. path. Anat.*, 1932, *53:* 422–428.
12. Jones, S. H., and Klinck, G. H., Jr. *Torula histolytica* (*Cryptococcus hominis*) meningitis: case report and therapeutic experiments. *Ann. intern. Med.* 1945, *22:* 736–745.
13. Krainer, L., Small, J. M., Hewlitt, A. B., and Deness, T. A case of systemic torula infection with tumour formation in the meninges. *J. Neurol. Neurosurg. Psychiat.*, 1946, n.s. *9:* 158–162.
14. Mosberg, W. H., Jr., and Arnold, J. G., Jr. Torulosis of the central nervous system: review of literature and report of five cases. *Ann. intern. Med.*, 1950, *32:* 1153–1183.
15. O'Neill, F. J., Newcomb, A. L., and Nielsen, C. S. Cryptococcus meningitis. Report of a case. *Nav. med. Bull., Wash.*, 1949, *49:* 300–305.
16. Rand, C. W. Coccidioidal granuloma. Report of two cases simulating tumor of the spinal cord. *Arch. Neurol. Psychiat., Chicago*, 1930, *23:* 502–511.
17. Stone, W. J., and Sturdivant, B. F. Meningo-encephalitis due to *Torula histolytica*. *Arch. intern. Med.*, 1929, *44:* 560–575.
18. Swanson, H. S., and Smith, W. A. Torular granuloma simulating cerebral tumor. Report of two cases. *Arch. Neurol. Psychiat., Chicago*, 1944, *51:* 426–431.
19. Verbiest, H. Personal communication.
20. Voyles, G. Q., and Beck, E. M. Systemic infection due to Torula histolytica (cryptococcus hominis). 1. Report of four cases and review of the literature. *Arch. intern. Med.*, 1946, *77:* 504–515.
21. Warvi, W. N., and Rawson, R. W. Torula meningitis. *Arch. intern. Med.*, 1942, *69:* 90–98.


# ARTERIOVENOUS ANEURYSM OF THE BRAIN

## REPORT OF CASE CURED BY CLIPPING MIDDLE CEREBRAL ARTERY


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The possibility of curing arteriovenous aneurysms of the brain by craniotomy and direct surgical attack deserves emphasis in light of our present day greater diagnostic accuracy by cerebral arteriography, increased knowledge of the nature of these lesions, and improvement in surgical technic. In the past, most of them have been surgically exposed on the erroneous preoperative diagnosis of focal epilepsy caused by tumor. When the lesion was recognized, the skull was usually closed without treating it specifically for fear of encountering fatal hemorrhage.

Many patients with this disorder have had carotid ligation performed with questionable improvement.

The 2 cases of arteriovenous aneurysm of the middle cerebral artery here reported and selected from a considerable number of these lesions of the brain seen in the past 20 years, came under my care at very nearly the same time and illustrate (A) the futility of hoping for a cure by carotid ligation (Case 1), and (B) the possibility of producing a cure by ligation of the feeding artery, the middle cerebral (Case 2).

*Case 1.* D.L., male, aged 66, was first seen in the Neurological Out-Patient Department on Feb. 17, 1947, with the complaints of recent numbness of the left arm and face, and focal

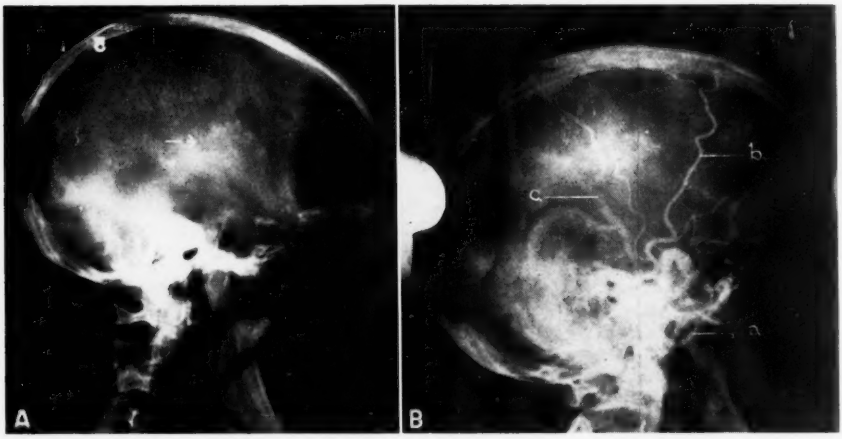


FIG. 1. *Case 1.* (A) Calcified mass indicates probable arteriovenous aneurysm but other types of tumor might cast a shadow identical to this. (B) Angiogram showing early filling of large cortical vein (c) in early arterial phase of injection due to arteriovenous fistula. The temporal (b), middle meningeal and internal maxillary arteries (a) are filled because of anomalous branching of these vessels from the internal carotid well above their usual location. Note also that the cerebral arteries show poorly because the contrast medium has barely begun the arterial phase. A later exposure (which was not taken) should have demonstrated the artery feeding the vascular mass.

epilepsy since the age of 21. The convulsions were often associated with prodromal symptoms of numbness of the tip of the tongue and a peculiar taste. The attacks always started with rubbing the tongue against roof of mouth, and movements and numbness of left face and arm followed by a grand mal attack. Occasionally his attacks included only the aura described, with numbness of the arm and fingers, lasting 10 to 15 minutes. Following the attacks he frequently had numbness of the fingers for several days and a right frontal headache. On rare occasions he had had visual hallucinations in the left visual field following an attack characterized by seeing people, chickens and trolley cars.

Examination revealed a slight weakness and clumsiness of the left arm, and hyperactive tendon reflexes in the left arm and leg without sensory impairment. Roentgenography showed an irregular calcification in the right frontoparietal region and a pineal shift. Visual acuity and fields were normal. A brain tumor was diagnosed, and surgical care was advised.

On May 11, 1948, he was admitted to the Neurosurgical Service because his symptoms had become annoying and the attacks more frequent.

*Examination.* He now showed a left homonymous hemianopsia, and marked weakness of the arm, leg and lower face on the left with all types of sensation impaired over the left half of the body. EEG showed a right frontal lobe "paroxysmal disturbance" with no delta activity. On May 21 arteriography was performed on the suspicion that a right cerebral vascular abnormality was present. This test was not satisfactorily diagnostic because of the bizarre pattern shown (Fig. 1).

*1st Operation.* On June, 4 1948, craniotomy was performed with the finding of a large arteriovenous lesion of the frontotemporoparietal region which appeared to be fed by the middle cerebral vessels in the Sylvian fissure. The veins running from the Sylvian fissure upward to the sagittal sinus and downward to the lateral sinuses were enlarged and tortuous, and arterial blood could be seen swirling through them. Many small snarls of arterioles and venules, which characterize these lesions, were also present (Fig. 2). Nothing was done to the lesion and the skull was closed tightly.

FIG. 2. *Case 1.* Huge pulsating cortical veins shown at operation. Arterial blood could be seen and felt inside these vessels.

*2nd Operation.* On June 14, 1948, the right internal carotid artery was ligated with an aluminum clip.

*Course.* On Aug. 19, 1948, he still complained of a right frontal headache, but it was improved. He stated there had been no seizures since operation.

On April 1, 1949, he was readmitted to the hospital in an unconscious state. His daughter stated that his general condition had gradually deteriorated. He had had "shaking" attacks frequently but no unconscious attacks. The night before he had complained of headache, and the next morning he could not be aroused. The CSF was bloody and the pressure 310. He died 24 hours after admission.

*Necropsy* showed an arteriovenous anastomosis (congenital) in the right cerebral hemisphere being fed by the middle cerebral artery (Figs. 3 and 4). There was a large subdural clot from rupture of a cortical vein which was the immediate cause of death.

The next case is of interest because the pathological nature of the aneurysm was almost identical with Case 1. A cure was rather easily produced by clipping the entering middle cerebral artery, and prompt recovery ensued.

*Case 2.* J.McD., female, 23, was admitted Jan. 17, 1949, in a comatose state. She had vom-

ited and suddenly become unconscious 24 hours before, without apparent cause or complaints. She had moved her extremities slightly—perhaps more on the left—and had yawned. She apparently always had been in good health and had had 3 normal pregnancies.

*Examination* revealed a complete right hypesthesia and hemiplegia, inability to speak, and somnolence. The left pupil was larger than the right; there was no edema of the discs. CSF was bloody; pressure 260.

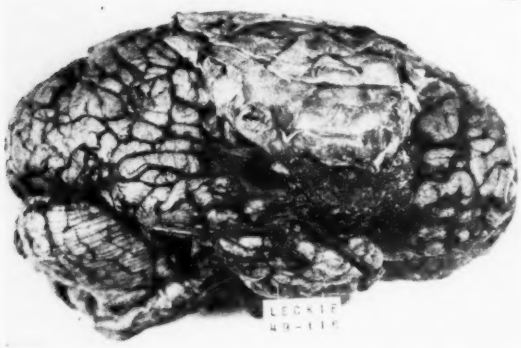

FIG. 3. *Case 1.* Gross specimen shows huge mass of vessels between the right temporal and frontal lobes. It was tightly adherent to the dura, which is shown above it.

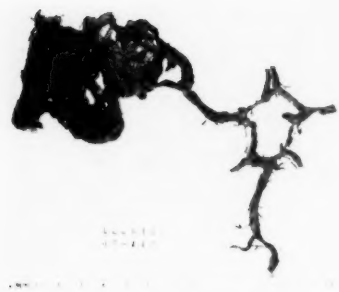

FIG. 4. *Case 1.* Tortuous, snarled arteriovenous mass with the enlarged middle cerebral artery which "fed" it, after dissecting it from the brain.

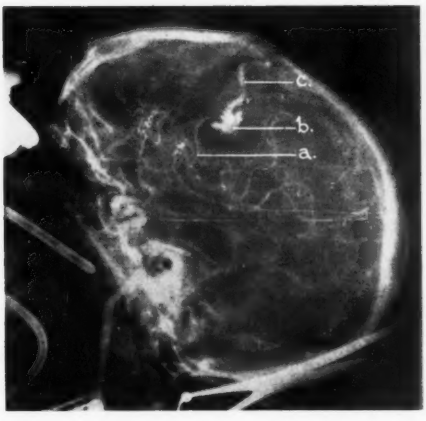


FIG. 5. *Case 2.* Angiogram showing arterial phase with a branch of the middle cerebral (a) "feeding" it. The large vein (c) draining from the vascular mass (b) is clearly demonstrated.

On Jan. 19, 1949 she recognized her relatives and co-operated in her examination. She was unable to speak and had a complete right hemiplegia. It was noted that on smiling, her right lower face movements were almost normal; while forced voluntary facial movements showed a complete lower facial paralysis. By Jan. 27, 1949, she could barely move her right leg and arm, but she was speechless. Arteriography showed an arteriovenous lesion of the left middle cerebral artery (Fig. 5).

*Operation.* On Feb. 28, 1949, craniotomy was performed. An abnormal vascular pattern

was disclosed. The veins were large, tortuous and filled with pulsating arterial blood. A large hematoma, $2\frac{1}{2}$ inches in diameter, was found beneath the cortex in the tip of the temporal lobe and extending into the frontal and parietal lobes. This was emptied of a solid clot, and by placing a finger inside the cavity remaining, the arterial supply to the veins could be palpated between the finger and thumb. One large surface artery was clipped without altering the thrill and pulsation, so it was apparent that the entire middle cerebral artery would have to be clipped to close all arteriovenous communication. Accordingly, the frontal lobe was lifted and a clip placed on the middle cerebral artery 3 mm. beyond its origin from the carotid. Immediately the thrill, pulsation and swirling blood ceased in the cortical vessels.

*Postoperative Course.* Her recovery was dramatic. Speech and the use of the right leg and arm returned in a period of 2 or 3 weeks to the point where they were useful to her. For some strange reason she had a postoperative paralysis of the left 3rd nerve which completely recovered in 8 weeks.

By Sept. 22, 1949 she was walking without help and doing all her own housework and shopping. The right arm and leg were still spastic and the right lower face was weak, but this was not apparent on smiling (Fig. 6).

FIG. 6. *Case 2.* Showing residual facial paresis after operation (A) on voluntary unemotional movement; (B) on smiling.

Since this patient's principal, if not entire, arterial supply to the cerebral arteriovenous communication has been eliminated, I anticipate a permanent cure of the fistula. It is a well-recognized fact that such a ligation of the middle cerebral artery in a normal person produces a hemiplegia and perhaps a fatality. In the light of the known over-adequacy of arterial development near fistulous openings, it appears that the risk in closing the middle cerebral artery in a patient with this type of lesion is not great.

The photograph of the necropsy specimen from Case 1 illustrates the possibility of curing these lesions by extirpation and clipping of the entering vessel, as was done in Case 2, when the lesion is largely supplied by one entering artery. It will be noted that the snarled mass of arteries and veins is fed by the middle cerebral artery, which can be determined preoperatively by arteriography. Its ligation leaves the mass of limp and pulseless vessels. Subsequent resection of any grossly enlarged, calcified vessels and hemorrhage can presumably be done with little danger of

hemorrhage. This specimen also demonstrates the localized snarl of vessels through which the operator must go if he approaches alongside of it to ligate the entering vessels at its base. The massive hemorrhage incident to dissecting through the numerous cortical veins filled by arterial pressure is reason enough to discourage the boldest brain surgeon. Since it is probably safe enough to clip the entering middle cerebral artery in these lesions, as shown by Case 2, this should be the procedure of choice where it appears to be the major arterial supply to the fistula. The exposure of this vessel can be greatly facilitated by withdrawing cerebrospinal fluid by spinal puncture. Otherwise, it may be technically impossible except when room is obtained through a preliminary evacuation of a large degenerated, subcortical clot.

### CONCLUSIONS

Case 1 of this report demonstrates the typical antemortem and postmortem pathologic picture of arteriovenous aneurysm of the brain vessels and the futility of carotid ligation as a method of preventing rupture and death by hemorrhage.

Case 2 illustrates the feasibility of direct ligation of the artery "feeding" the aneurysm for the production of a cure. This last case emphasizes the necessity of continuing the detailed study of pathologic lesions that are seemingly impossible to cure so that those that appear incurable at the present may be included in the easily curable of the not too distant future.

## PROGRESSIVE EXTRAPERIORBITAL HEMATOMA

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Orbital hematoma occurs so commonly in craniofacial injuries that it deserves no further comment. Progressive extraperiorbital hematoma, however, is a condition with special diagnostic and therapeutic features which hitherto seems to have attracted but little attention in the literature.† Extraperiorbital hematoma designates hemorrhage between the bony orbit and its periosteum, the periorbita (Fig. 1).

The following case is reported as an illustrative example.

Butterworth Hosp. No. 87042. W.H., male, aged 27 years. Admitted: June 9, 1949. Discharged: July 1, 1949.

*History.* The patient was admitted ½ hr. after he had fallen 10 ft., from a pile of lumber, on the left side of his head. At first he was completely unconscious, but within 1 hr. he partially recovered consciousness, complaining of severe left-sided headache.

*Examination.* He was restless, semistuporous and confused, but not aphasic. There was bleeding from the left nostril and a laceration of the left ear. A massive left orbital hematoma

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† Rare cases of severe exophthalmos in newborn, following birth injury, have been reported by Ehrenfest,[2] Borland,[1] and Philipsen.[3] The condition was attributed to either retro-orbital subperiosteal hematoma or thrombosis of orbital veins. On scrutiny of the original articles, however, these observations did not prove to be convincingly documented.

with moderate exophthalmos was present. All extra-ocular movements on the left were impaired; pupils and eyegrounds were normal. Except for a positive Babinski sign on the right no other abnormal neurologic findings were noted. His pulse was 56, respirations 20. B.P. 140/70.

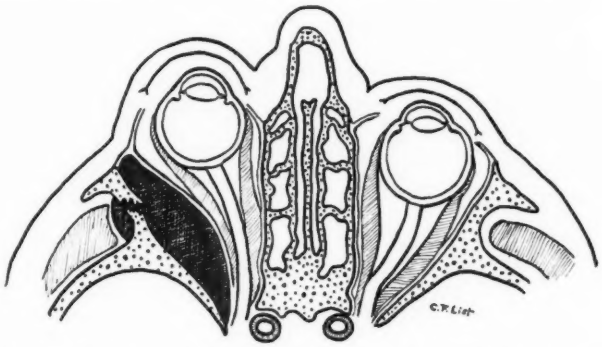

FIG. 1. Diagrammatic drawing of a head sectioned horizontally. A left-sided extraperiorbital hematoma arising from a fracture of the lateral wall of the orbit is indicated by the darkly shaded area. Note displacement of orbital contents with exophthalmos.

Roentgenograms of skull and orbit (Fig. 2) showed slightly depressed comminuted linear fractures of the left frontoparietal region with one crack extending through the greater wing of the sphenoid bone and lateral wall of the left orbit. There was also a fracture of the left frontozygomatic process.

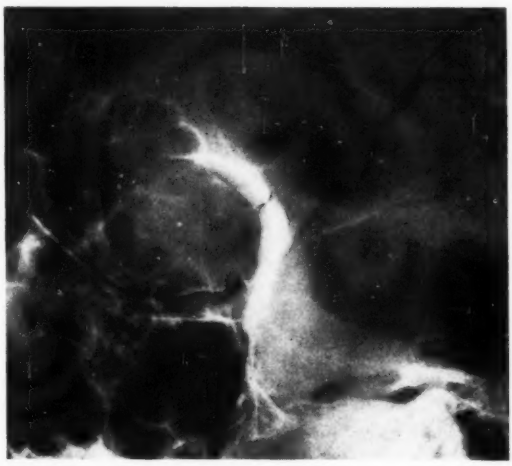

FIG. 2. Orbital roentgenogram showing fractures in frontotemporosphenoidal area and also of the frontozygomatic process.

*Course.* In view of the location of the skull fractures, the patient was carefully watched for signs of possible extradural hematoma, but fortunately this dreaded complication failed

to develop. His vital signs remained normal; the state of his consciousness cleared and no evidence of a serious intracranial lesion developed.

He continued, however, to suffer from severe left frontoparietal headaches. Five or 6 days after the injury, the orbital hematoma began to recede; the edematous and hemorrhagic discoloration of the left eyelids lessened, yet the left proptosis remained unchanged. On the 8th day he still complained of severe left frontotemporal headaches, and also blurred left vision. Even though the lid hematomas had further subsided, the left exophthalmos had increased and chemosis of the conjunctiva had developed. No measurements of the degree of protrusion of the eyes were made since an exophthalmometer was not available. Neither a bruit was heard on auscultation of the left orbit and temple, nor pulsation of the left eyeball seen. There was slight divergent strabismus on the left. The left medial rectus, inferior rectus, and superior oblique were paretic and there was also slight weakness of the levator palpebrae, superior rectus and inferior oblique, but the lateral rectus functioned almost normally. The slightly smaller left pupil showed diminished reaction to light. There was nasal blurring of the left optic disk with some retinal edema and venous engorgement. No field defect could be made out on gross confrontation test. There was hypesthesia in the ophthalmic division of the left 5th nerve but the left corneal reflex was normal.

A progressive subperiosteal (extraperiorbital) hematoma was suspected, originating from the orbital fracture line. The patient was treated conservatively for a few days with hot, wet, local applications. On the 11th day, however, it was observed that the left eye had protruded even more, and that slight exposure keratitis had developed with increased blurring of vision. Because of the progressive symptomatology, operation was then decided upon.

*Operation,* June 23, 1949 (12 days after the injury), under local anesthesia. A straight incision was made in the left temporozygomatic region, beginning at the posterior superior margin of the zygomatic arch and extending to the frontozygomatic process parallel to the course of the upper facial nerve fibers. After incision of skin and superficial fascia, one branch of the facial nerve was seen and carefully protected. The temporalis fascia and muscle were split and the muscle was detached from the anterior part of the temporal fossa and frontozygomatic process. After the lateral wall of the orbit and greater wing of the sphenoid had thus been exposed, a fracture line was seen in the greater wing of the sphenoid. A trephine opening was made through the lateral wall of the orbit and enlarged to the size of a 25-cent piece. Immediately a considerable amount of dark liquid blood escaped through the opening from the extraperiorbital space (Fig. 1). The periorbita appeared detached and displaced away from the orbital bone by some semisolid clots. After the clots had been carefully removed by suction, the entire lateral and inferior aspect of the periorbita was clearly exposed. The periorbita was split for decompressive purposes, permitting extrusion of the orbital contents. The orbital fat contained no gross hemorrhage. A Penrose drain was left between the periorbita and the bony orbita wall, and the wound was loosely closed in layers of silk. The exophthalmos was found to be reduced about 50 per cent at the end of the operation.

*Postoperative Course.* The drain was removed after 24 hrs. On the 2nd day, the exophthalmos was receding and extra-ocular movements were much improved. The severe headaches had subsided. On the 6th day further recession of exophthalmos was noted, but slight fullness in the temple remained. The eye movements were practically normal now. The patient still complained of blurred vision, and funduscopic examination revealed a left optic papillitis of 1 D. Lumbar puncture showed clear, colorless CSF, with an initial pressure of 290 mm.; W.B.C. 2; total protein 50.2; all other reactions normal. The patient was discharged on July 1, 1949, the 8th postoperative day.

When last seen on July 30, 1949, he complained of slight left temporal pain on chewing. His operative scar was sunken in. The left eye did not protrude; extra-ocular movements and fundi were normal.

## COMMENT

As any fracture may be associated with subperiosteal hemorrhage, fractures of the orbit may cause extraperiorbital bleeding. As a rule, this predominantly venous

hemorrhage remains of minor proportion. In the case presented here, however, a slow ooze continued, leading to a progressive displacement of the eyeball and compression of the orbital contents. It is tempting to compare this situation with a gradually developing extradural hematoma.

The clinical syndrome was characterized by gradually increasing exophthalmos, chemosis, exposure keratitis, impairment of vision with papillitis, extra-ocular palsies, and severe orbitotemporal headaches. In the differential diagnosis, one has to consider traumatic arteriovenous fistula of the carotid in the cavernous sinus (pulsating exophthalmos), thrombosis of the orbital veins, and finally, orbital cellulitis caused by infection. As to treatment, it is advisable to adopt at first a conservative course since minor extraperiorbital hemorrhage is self-limited and resorbs spontaneously. If, on the other hand, the exopthalmos progresses and endangers the cornea and vision, surgical steps should not be delayed until irreversible damage occurs. Lateral decompression of the orbit (Krönlein's operation) is an effective and safe procedure which may be easily carried out under local anesthesia. It is essential not to traumatize the upper branches of the facial nerve since weakness of the orbicularis oculi may cause further damage to the protruded eye by exposure and thus necessitate tarsorrhaphy. Splitting of the periorbita probably assures a better decompression of the orbital contents.

SUMMARY

A case is reported of progressive extraperiorbital hematoma following fracture of skull and orbit. The clinical symptomatology consisted of progressive exophthalmos, extra-ocular palsies, optic neuritis with visual loss, and severe frontotemporal pain. The condition was cured by lateral decompression of the orbit with removal of the hematoma.

REFERENCES

1. Borland, H. H. A case of exophthalmos in the newly born. *Lancet*, 1904, *2:* 1344–1345.
2. Ehrenfest, H. Birth injuries of the child. *New York: D. Appleton & Co.*, 1922, xiv, 221 pp. (see p. 130).
3. Philipsen, H. Note sur un cas d'exophtalmie chez un nouveau-né. *Ann. Oculist., Paris*, 1891, *106:* 420–422.

# INTRASPINAL EPIDERMOID TUMOR

## CASE REPORT AND DISCUSSION

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Epidermoid and dermoid tumors of the spinal canal, together with teratoids, teratomas, and communicating dermal sinuses, form a rarely occurring but clinically important group of intraspinal lesions. They are considered together because of their somewhat common origin from an embryonal accident.

In 1949 Sachs and Horrax[1] published an exhaustive review and tabulation of the

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cases reported in the literature. They added a case of their own along with an unpublished case of Furlow. Their review brought the total of published cases to 61 of epidermoids and dermoids and 25 of teratoids and teratomas. It was pointed out that 14 of the entire group had an associated dermal (pilonidal) sinus passing through the dura and communicating with the tumor. For detailed features and a complete bibliography of the subject, the reader is referred to their paper.[1] Our own report will serve to emphasize the salient clinical features of this group of lesions, and to record another case of intraspinal epidermoid tumor.

The nomenclature used by Sachs and Horrax is a pathological one, but from a

FIGS. 1 and 2. Views of patient to show atrophy of legs. Note clubbing of right foot.

practical clinical standpoint all of these tumors can be conveniently grouped together.

The clinical picture of these tumors is generally that of long-standing symptoms of spinal cord or nerve root compression, frequently dating from childhood. The incidence is higher in males, in the younger age group. The diagnosis is most frequently made in the first 4 decades, although a case in the 8th decade has been reported. Radiographs of the spine generally show widened interpedicular spaces, and may show irregular areas of calcification. Frequently associated anomalies of the vertebrae are present. An intermittently draining midline sinus may have been noted.

The results of surgical excision have been generally good, although conservatism is advised in attempting complete removal of the tumor capsule, since further cord

damage may result. The benign character and slow rate of growth of the dermoids and epidermoids make complete removal unnecessary to obtain a satisfactory result.

The following case is of particular interest because of the long-standing history (42 years), the size of the lesion, and the satisfactory result.

## CASE REPORT

H.G.B., a 52-year-old businessman, was first seen Mar. 19, 1949, complaining of recurring cramps in the left great toe of at least 20 years' duration. Upon questioning, it was revealed that at the age of 10 some difficulty involving the right foot was first noted, and a diagnosis

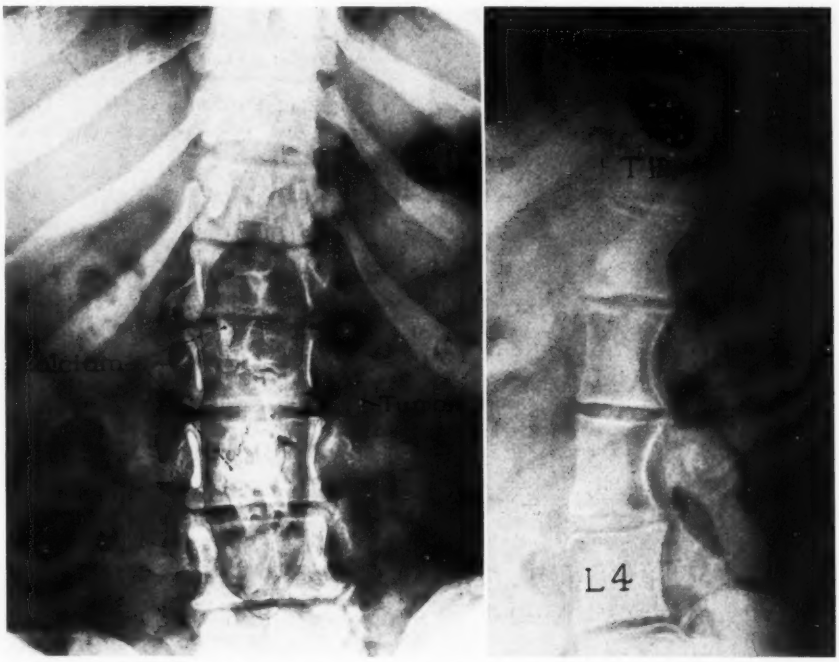


FIG. 3 (*left*). Retouched X-ray showing widening of spinal canal and erosion of pedicle.
FIG. 4 (*right*). Showing erosion of the bodies of the vertebrae.

of poliomyelitis was made at that time. There had been disability of the right leg and foot since then, it having never grown in size or length as the left and having acquired an inversion deformity. Numerous local operative procedures had been performed in an attempt to correct the inversion and to stabilize the ankle. Since childhood, ulcerations had appeared intermittently over pressure points of this foot. He had had recurrent attacks of left sciatic pain since 1921. The cramps in the left foot had grown worse during the past 5 years. Local nerve resections about the ankle and foot had been done without relief. No sexual difficulties had been noted.

*Examination.* He was of short stature, with an obvious disproportion between the length of his trunk, which was that of a larger person, and the legs, which appeared abnormally short and poorly developed. Obvious atrophy of both legs below the knee was noted, and

relative atrophy of the right thigh as compared to the left (Figs. 1 and 2). The right leg was considerably shorter than the left and the right foot was fixed in an inversion deformity. Healed trophic ulcers were present over the heel and opposite the distal end of the 5th metatarsal bone on the right foot. The left foot appeared normal, but numerous attacks of involuntary muscle spasm appeared, with associated dorsiflexion of the toes.

The abdominal reflexes were present, but diminished when tested over the 12th thoracic and 1st lumbar dermatomes. The cremasteric responses were brisk during the testing of the abdominal reflexes, but absent upon stroking the thighs. The right knee and ankle jerks were present and hypoactive, while the left knee and ankle jerks were totally absent. Total anesthesia of the left foot in the distribution of the 5th lumbar and 1st sacral dermatomes was present. Hypesthesia and hypalgesia in the other sacral dermatomes were present, but as the lower sacral dermatomes were approached, sensation became normal. The same type of sensory pattern was present in the right lower extremity, except that there was no total loss of sensation at any place. Marked weakness of the muscles of the calves was present bilaterally, although the strength of the thigh muscles, both anterior and posterior groups, was normal.

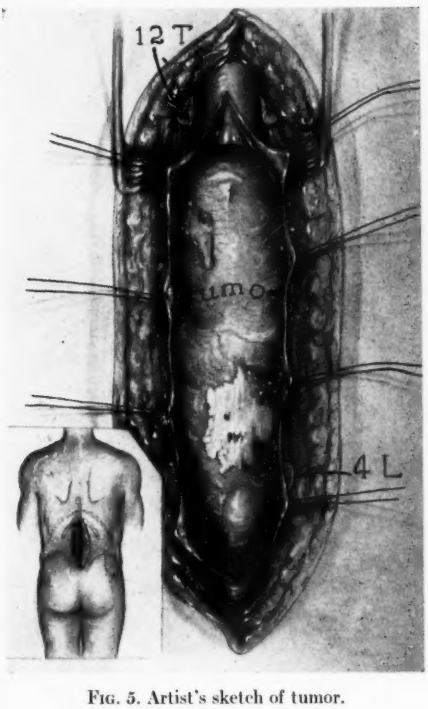


FIG. 5. Artist's sketch of tumor.

As he stood, there was a striking scoliosis of the spine, apparently compensatory to the tilt of the hip, incident to the shortened right leg. No tenderness over the spine was present.

X-rays of the spine (Figs. 3 and 4) revealed marked widening of the interpedicular spaces at L 2-4, and in the lateral view, erosion of the dorsal surfaces of the bodies of L 1-4 was noted. Irregular areas of intraspinal calcification were noted in this region.

*Operation.* On April 1, 1949 the spines and laminae of T 12 through L 4 were removed, exposing the widened spinal canal and noticeably thinned dense dura, through which a whitish appearing tumor could be seen, extending from L 1 through L 4. Above this the dura appeared its normal bluish color and pulsations could be seen. There was no pulsation opposite or below the tumor mass. The dura was opened in the midline, and due to close adherence of the tumor to the dura, the tumor capsule was also opened along most of its course. The tumor was found to extend from an abnormally widened and flattened conus to the 4th lumbar level, with the nerve roots passing anteriorly and laterally on both sides (Fig. 5).

The interior of the tumor contained cheesy, amorphous degenerate material, generally of a yellowish color, but in the peripheral portions, appearing pearly white, with a definite satin-like sheen. The material was removed by spooning, irrigation, and suction leaving behind a glistening, thin, avascular membrane, whose interior was irregularly coated with calcific plaques. Due to the obvious dense adherence of the nerve roots to the capsule anteriorly and laterally, no attempt was made to dissect these free. A portion of the free-lying capsule was removed for pathological examination. The thinned dura was closed carefully, and in one place, a 1 cm. defect was closed by a mattress suture incorporating a small stamp of gelatin foam. The wound was carefully closed in layers.

*Pathologic Report.* "The debris forming the greater part of the tumor is composed entirely of keratinized and degenerate epithelial cells. The capsule of the tumor (Fig. 6) shows it to be formed by an orderly layer of stratified squamous epithelium with proliferation of keratinized cells into the tumor cavity. Outside of this there is a thin zone of fibrous tissue. No definite hair follicles, sebaceous or sweat glands are noted."

*Microscopic Diagnosis.* Epidermoid of spinal canal.

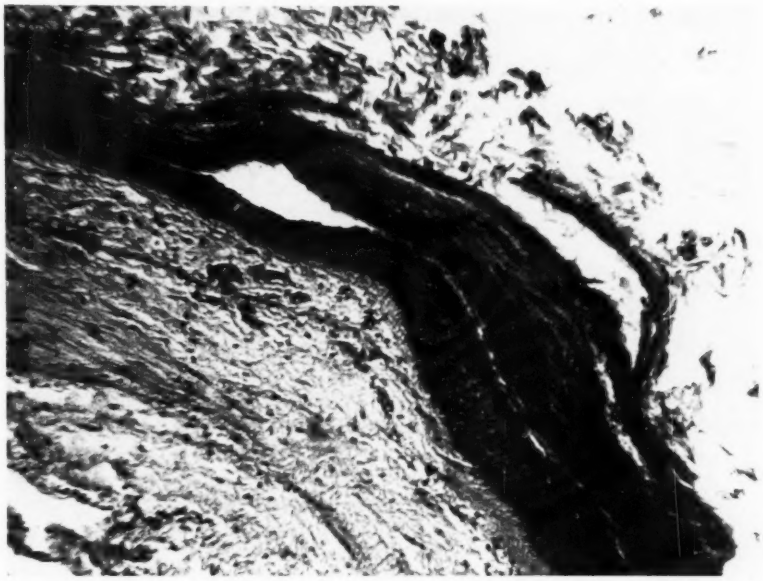

FIG. 6. Photomicrograph of tumor capsule.

The *postoperative course* was relatively uneventful with the exception of a spinal fluid leak which was controlled by some deeply placed sutures. There was difficulty in voiding for approximately 10 days. The patient had considerable relief of the leg and foot pain of which he had complained, although he continued to have occasional cramps. A subcutaneous spinal fluid lake developed which was repaired 5 months after his initial surgery, without recurrence. There has been a vague but definite subjective improvement in sensation in his legs, although objectively this cannot be demonstrated. There is no evidence of any increase in his neurologic disability since surgery.

## SUMMARY

A brief discussion of the features of various intraspinal embryonal tumors is made.

The importance of consideration of these lesions in the diagnosis of long-standing cases of spinal cord involvement is emphasized.

An additional case of intraspinal epidermoid tumor is presented, bringing to 62 the number of cases now recorded.

## REFERENCE

1. SACHS, E., JR., and HORRAX, G. A cervical and a lumbar pilonidal sinus communicating with intraspinal dermoids. Report of 2 cases and review of the literature. *J. Neurosurg.*, 1949, *6:* 97–112.

# DELIBERATE THROMBOSIS OF INTRACRANIAL ARTERIAL ANEURISM BY PARTIAL OCCLUSION OF THE CAROTID ARTERY WITH ARTERIOGRAPHIC CONTROL

## PRELIMINARY REPORT OF A CASE

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Accepted methods of treatment of intracranial arterial aneurisms consist of bed rest, carotid ligation, or direct surgical attack. In general, the best results with aneurisms below the circle of Willis have been attained by carotid ligation.[5] We consider them probably due to thrombosis within the aneurism. Occasionally, carotid ligation has an inadequate effect. In these cases there is subsequent rupture of the aneurism. Sometimes carotid ligation causes so much decrease in blood flow that there results cerebral anemia with[8] or without[6] arterial thrombosis. The ideal result, then, is enough impairment of arterial flow to produce thrombosis of the aneurism alone, without causing either cerebral anemia or thrombosis of the parent artery.

In one case of saccular aneurism of the internal carotid artery near its bifurcation, this goal has apparently been achieved by partial occlusion of the common carotid artery. It has been verified by carotid arteriography. The widespread implications of this procedure seem to justify this preliminary report.

### REPORT OF CASE

*Male, aged 48. Headaches 2 years. Spontaneous subarachnoid hemorrhage. Angiography: sessile aneurism of left internal carotid just below its bifurcation. Bed rest 5 weeks: no effect on aneurism. Digital carotid compression for 1 hour: no thrombosis produced. Partial occlusion of left common carotid with tantalum clip for 1 week: thrombosis of about 80 per cent of aneurism. Uneventful thoracotomy for what proved to be healed tuberculoma. Subsequent arteriogram: nearly total thrombosis of aneurism without encroachment on arterial lumen.*

On March 24, 1950 a 48-year-old engineer was admitted to the Syracuse University Hospital some hours after collapsing while shoveling snow. During the previous 2 years, he had had mild frontal headaches, particularly on the left side.

On admission, he had hyperactive deep reflexes and absent superficial reflexes. There were no definite signs of meningeal irritation or neural dysfunction. Lumbar puncture yielded very bloody CSF under pressure of 220 mm. The following day he was transferred to the Syracuse Memorial Hospital. The neck now was stiff and Kernig's sign positive. Roentgenograms of the skull were normal except for slight backward displacement of pineal body. A chest film demonstrated a round area of increased density in the left upper lobe. An EEG indicated a diffuse mild abnormality without evidence of localization.

A *left* carotid angiogram on March 27 revealed an aneurism, 20×15×11 mm. with a broad base, arising from the internal carotid artery, just above the anterior clinoid process (Fig. 1, A and B). There was poor filling of the vessels beyond the aneurism. *Right* carotid arteriograms with simultaneous compression of the left carotid, showed good filling of both anterior and middle cerebral arteries with poor filling of the aneurism. These films (in Chamberlain-Towne view) showed some squaring of the left middle cerebral artery, suggestive of cerebral swelling (Fig. 1 C).

The patient was placed at complete bed rest for a month, following which there was no change in the chest films. During this period, there were occasional bifrontal headaches lasting from 1 to 1½ hours.

Left carotid angiography (2nd exam.) on April 3, 1950, revealed no change in appearance of the aneurism. Both anterior cerebral arteries were well visualized. Ten days later, the EEG was normal, even after left carotid compression for 25 minutes.

We then wished to determine whether carotid compression would produce stasis within the aneurism. If the patient were supine, hyperextending his neck would bring the fundus of the aneurism into a dependent position. Then carotid angiography could be performed with carotid compression below the needle. Since 35 per cent diodrast® has a specific gravity (1.185) greater than that of blood (approximately 1.060), stasis would show as a pool of diodrast® in the dependent aneurismal fundus.

Accordingly, on April 26, 1950, left carotid angiography (3rd exam.) was done during

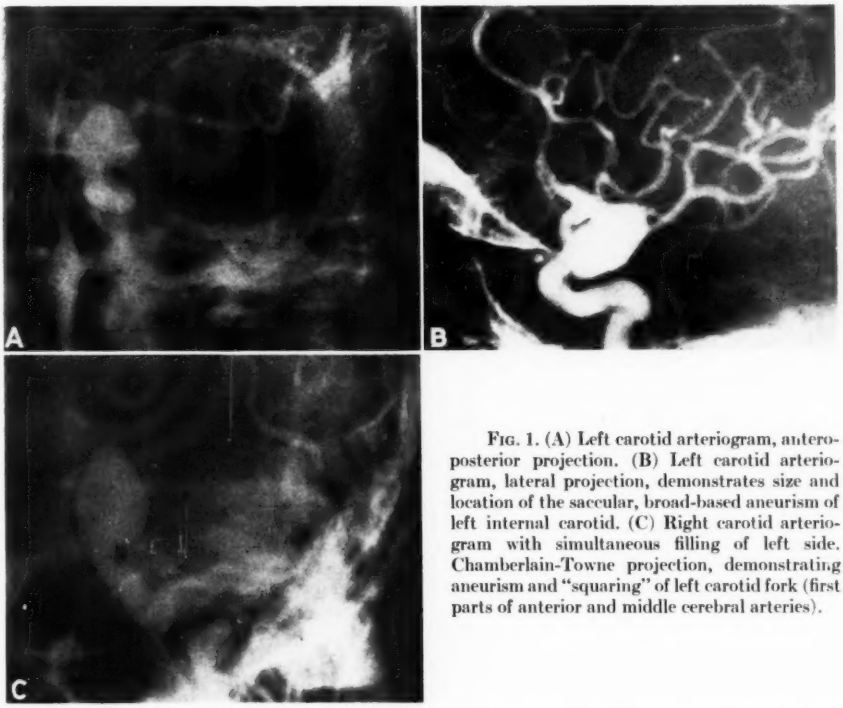


FIG. 1. (A) Left carotid arteriogram, anteroposterior projection. (B) Left carotid arteriogram, lateral projection, demonstrates size and location of the saccular, broad-based aneurism of left internal carotid. (C) Right carotid arteriogram with simultaneous filling of left side. Chamberlain-Towne projection, demonstrating aneurism and "squaring" of left carotid fork (first parts of anterior and middle cerebral arteries).

proximal compression of the left common carotid. A polyethylene catheter was inserted into the left internal carotid through a #14 gauge Tuohy needle. The mean blood pressure in the right brachial artery equalled the pressure within the left internal carotid. The catheter could be seen in the angiogram to extend up the internal carotid to the base of the skull. Compression of the left common carotid caused a 40 per cent drop in intracarotid pressure. With digital compression of the left common carotid, 15 cc. of 35 per cent diodrast® were injected. The first film made at the end of injection revealed filling of the internal carotid from the point of injection as well as of the aneurism and adjacent arteries (Fig. 2 A). Further films were made at intervals of approximately 6 secs., 12 secs., and 1 min. after injection. Each of these showed the fundus of the aneurism. About 40 per cent of the projected area of the aneurism remained opaque in the last exposure (Fig. 2 B), proving that considerable stasis in the aneurism had been caused by left common carotid compression.

Accordingly, we considered that prolonged compression might cause thrombosis. After 17 mins. of continuous pressure, the patient complained of faintness and had slight convulsive movements of the right arm. The pressure was released momentarily. The compression was then resumed and another angiogram made. Once again the aneurism was completely filled with dye. At the end of 26 mins., the patient again felt faint and pressure was momentarily released. During the remainder of an hour, the pressure had to be released for about 10 secs on each of 5 occasions. Then deliberate stimulation showed that the patient's left carotid sinus was hypersensitive (bradycardiac type). At the end of the hour, another injection revealed complete filling of the aneurism once again (Fig. 2 C). No thrombosis had been produced.

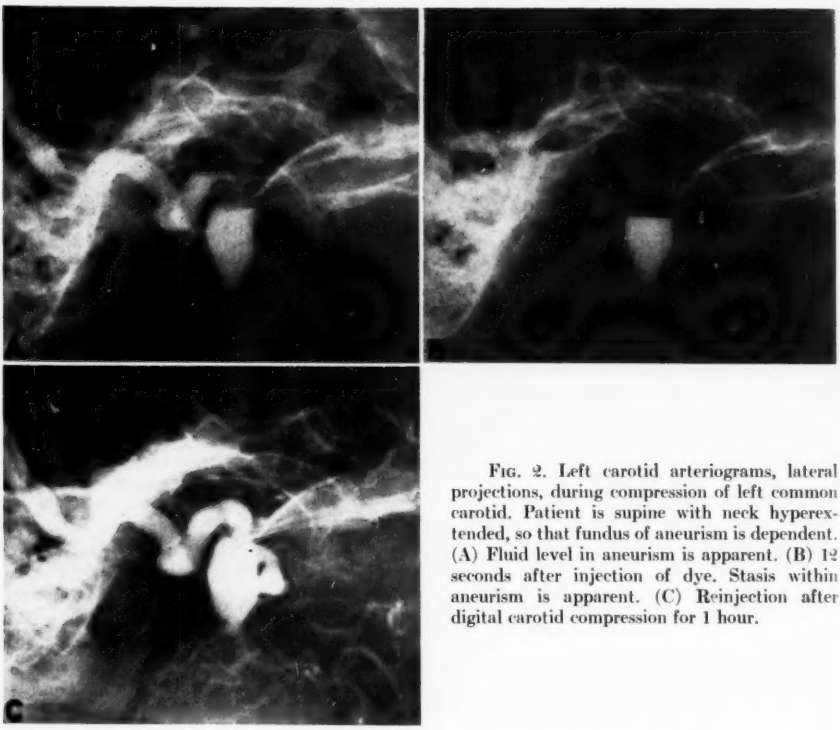

FIG. 2. Left carotid arteriograms, lateral projections, during compression of left common carotid. Patient is supine with neck hyperextended, so that fundus of aneurism is dependent. (A) Fluid level in aneurism is apparent. (B) 12 seconds after injection of dye. Stasis within aneurism is apparent. (C) Reinjection after digital carotid compression for 1 hour.

During prolonged compression, a constant glucose drip was kept 2″ or 3″, corresponding to 4–6 mm. of mercury, above the level of the intracarotid pressure. Then, whenever the compressing fingers weakened, the glucose stopped flowing. This provided a reliable, and relatively simple, way of checking the effectiveness of digital carotid compression.

Studies of the early films of this procedure suggested that when the left common carotid was firmly compressed, there was greater blood pressure in the posterior communicating than in the anterior cerebral. The evidence was two-fold: (a) as dye was being slowly washed away from the aneurism, there was a little seriflike point at the anterior edge of the dye level in the aneurism (Fig. 2 B) and (b) when dye was being injected it went into the anterior and middle cerebral arteries but not into the posterior communicating artery (Fig. 2 C).

On May 3, 1950, partial occlusion of the left common carotid artery was effected by means

of a tantalum clip. The common carotid was exposed. After a short period of arterial hypotension during the exposure, the brachial blood pressure became steady at about 130/70. The pressure within the common carotid was 61 mm. of mercury. This was determined, of course, with the glucose drip.[2] With total occlusion, the pressure was 42 mm. of mercury, a drop of about 33 per cent. A tantalum clip, about 1 cm. wide, had been prepared so that its edge was beveled away from the artery. Slight changes in adjustment of the clip caused large changes in carotid pressure, namely between 42 mm. and 61 mm. of mercury. Finally, the clip was adjusted so that the reading was 51 mm. This figure corresponds to a drop of 50 per cent of what total occlusion would cause or 16 per cent absolute drop. The open end of the clip was tied with a No. 30 stainless steel wire. The wound was closed without drainage. The patient had no ill effects.

On May 10, 1950, an x-ray film of the chest showed no change. Left carotid angiography (4th exam.) showed the dye to fill well the internal carotid artery and its branches. The dye was seen in the most antero-inferior portion (that is, at the hilus) of the previously described aneurism. Films made both in the dependent and lateral projections showed no filling of ap-

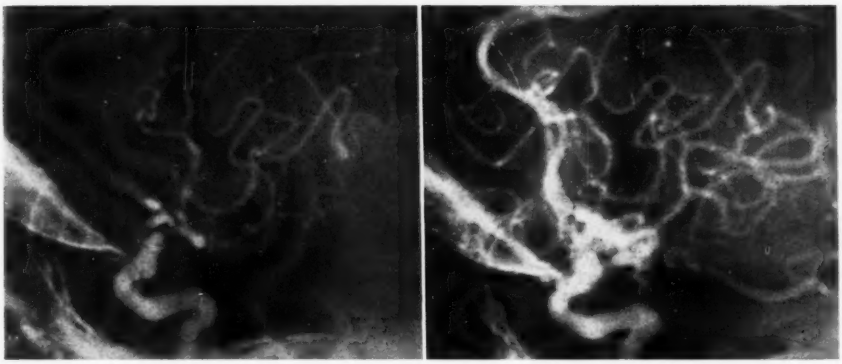

FIG. 3 (*left*). Left carotid arteriogram, lateral view, 1 week after partial occlusion of left common carotid with tantalum clip. Non-filling of fundus of aneurism with dye indicates thrombosis.

FIG. 4 (*right*). Left carotid arteriogram, lateral view, 1 month after partial occlusion of left common carotid. No definite evidence of residual aneurism. Note appearance, for the first time, of the left posterior communicating and posterior cerebral arteries.

proximately 80 per cent of the aneurism, with a straight *lower* margin of diodrast® (Fig. 3). The same result occurred with and without carotid compression. This arteriogram indicated that thrombosis of the fundus and adjacent portion of the aneurism had taken place.

On May 17, 1950, left thoracotomy was performed by Dr. Walter F. Bugden, who removed what proved to be a calcified tuberculoma from the left upper lobe of the lung. Convalescence was uneventful. The patient was discharged from the hospital 10 days after the thoracotomy. Mild headaches around the left eye persisted until June 3, 1950. Since then he has been free from symptoms.

On June 7, 1950, left carotid angiography (5th exam.) was performed. The mean intracarotid pressure was approximately 95 mm. of mercury. The lateral view revealed excellent filling of the internal carotid artery and its branches. For the first time, the left posterior communicating and left posterior cerebral arteries were filled. There was no definite evidence of residual aneurism. Furthermore, there was no encroachment on the lumen of the internal carotid artery as it passed the aneurism. There was some increased density of the dye entirely within the projection of the internal carotid. This density could represent the artery on end or possibly a small pocket of residual aneurism (Fig. 4).

All angiograms were performed percutaneously under local anesthesia, using 35 per cent diodrast®.[2] When last seen in September, 1950, the patient was entirely well and working regularly. He was delighted to be completely free from headache for the first time in 2 years.

## DISCUSSION

Spontaneous thrombosis of extracranial arterial aneurisms, without interference with the flow of blood through the parent artery, is not uncommon.[7] However, we have been unable to find in medical literature a report of such an occurrence in an intracranial aneurism. Nevertheless, such cases do occur. For example, Dr. Wardner D. Ayer[1] has had a case of a 51-year-old man who died of coal gas poisoning 5 weeks after a probable spontaneous subarachnoid hemorrhage. Autopsy revealed a thrombosed aneurism, 0.8 cm. in diameter, of the anterior communicating artery. Furthermore, Logue[3] performed carotid ligation in 3 cases of intracranial arterial aneurism. At craniotomy a week later, in each case he found the aneurism thrombosed as determined by palpation and by inserting a needle into the aneurismal sac.

In the case presented here the aneurism was at or just below the juncture of the left carotid and posterior communicating arteries. The location, broad pedicle and size of this aneurism would have made direct excision by craniotomy extremely dangerous. Conservative treatment (bed rest) for 5 weeks was employed, and arteriography demonstrated that no thrombosis of the aneurism had taken place. Carotid ligation was, therefore, decided upon. A partial ligation was to be preferred especially since the patient was to undergo thoracotomy soon afterward.

Before carotid ligation, right and left carotid angiography had been performed. Thus the presence of a patent anterior communicating artery and absence of a contralateral aneurism had been established. A Matas test, namely digital compression, had been carried out on the left common carotid artery. This compression for 25 minutes had caused no symptoms, no clinical signs and no change in the EEG.

One hour of almost continuous total compression of the left common carotid artery failed to produce thrombosis of the aneurism. The diodrast®, in contact with the wall of the aneurism for several minutes, might have caused irritation and thrombosis. It did not. Incidentally, diodrast® *in vitro*, that is in tubes of glass or lusteroid, is a powerful anticoagulant.[4]

This method of arteriographic control or observation of what is going on within the aneurism is obviously limited to those cases in which the aneurisms can be consistently demonstrated in arteriograms. It is not an uncommon experience in arteriography to have the blood flow past a patent aneurism without apparently filling it. Therefore, *lack* of demonstration of an aneurism in an arteriogram is reliable evidence of thrombosis only if (1) there is good visualization of the artery passing by the neck of the aneurism and (2) the patient was placed so that the fundus of the aneurism was lower, in relation to gravity, than its base. However, there can be positive arteriographic proof of the state of thrombosis of part of an aneurism (Fig. 3).

The original radiographs of Figs. 1 B, 3 and 4 were made with identical technic. The internal carotid artery and some of its intracranial branches appear smaller in the latter two figures than in the first. We ascribe this vasoconstriction to the partial ligation of the left common carotid artery. An important role in the development of intrasaccular thrombosis may be played by arterial spasm, which will be the subject of an early communication.

SUMMARY

A therapeutic goal for intracranial arterial aneurisms has been suggested: the deliberate thrombosis of the aneurism while sparing the parent artery. In the case reported this goal was attained by partial occlusion of a common carotid artery in the neck. We suggest percutaneous cerebral arteriography, as in this case, to control the treatment of most intracranial arterial aneurisms, whether treated by bed rest or carotid ligation.

REFERENCES

1. Ayer, W. D. Personal communication, 1950.
2. Ecker, A. The normal cerebral angiogram. *Springfield, Ill.: Charles C Thomas.* (In press)
3. Logue, V. Personal communication, 1950.
4. Lozner, E. L. Personal communication, 1950.
5. Poppen, J. L. Specific treatment of intracranial aneurysms. Experiences with 143 surgically treated patients. *J. Neurosurg.*, 1951, *8:* 75–102.
6. Schorstein, J. Carotid ligation in saccular intracranial aneurysms. *Brit. J. Surg.*, 1940, *28:* 50–70.
7. Shumacker, H. B., Jr., and Wayson, E. E. Spontaneous cure of aneurysms and arteriovenous fistulas, with some notes on intrasaccular thrombosis. *Amer. J. Surg.*, 1950, *79:* 532–544.
8. Voris, H. C. Complications of ligation of the internal carotid artery. *J. Neurosurg.*, 1951, *8:* 119–131.

# OPTO-CHIASMATIC ARACHNOIDITIS

## SURGICAL TREATMENT AND RESULTS

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MANUEL BALADO was the first[3] to explore the opto-chiasmatic region in a patient suffering from optic neuritis. In 1929, with Satanowsky,[8] he reported the results of the operations and prescribed the surgical therapeutics for cases of what was later to be identified as opto-chiasmatic arachnoiditis or "Syndrome of Balado."

A few months later (October 1929), Cushing[13,14] described the chiasmal syndrome at the XIII International Congress of Ophthalmology held at Amsterdam, and stated that surgical treatment could improve certain disturbances produced by lesions of the arachnoid restricted to the opto-chiasmatic region.

The process was later studied by many authors, Frazier,[18] Davis and Haven,[15] Vincent, Puech and David,[28] Bollack, David and Puech,[10] Alajouanine and Thurel,[1] Feld and Auvert,[17] Bruetsch,[11] Taptas and Dimopoulos,[26] and others.[2,5–7,9,12,16,19–25,27]

It is true, as Feld and Auvert[17] have stressed, that the anatomo-clinical definition of opto-chiasmatic arachnoiditis should be revised. A leptomeningitis limited to the region of the chiasmatic cistern undoubtedly is a lesion that indicates the existence of other disturbances in that zone and by no means constitutes in itself the entity producing loss of vision.

Essentially, the basic cause of the arachnoiditis is a disturbance of capillary permeability resulting from a vasodilatation reflex process produced by unknown factors in a predisposed terrain. Opto-chiasmatic arachnoiditis fundamentally is a neurovascular disturbance, which affects capillary permeability and produces exudative and cicatricial reactions.

*The leptomeningeal formations involving the optic nerves do not in themselves constitute the lesion, but indicate the existence of focal neurovascular disturbances.*

Endocrine disorders and allergic disturbances have been found to be the principal predisposing factors. Infections of the paranasal cavities, neurovirus processes, lues, tuberculosis,[4] etc., are frequently factors in the onset of the lesion. The action of the Koch bacilli is marked by aggression on

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the neurovascular system and by a tendency to produce vasodilatations in contrast to a true meningitis limited to the opto-chiasmatic region.

Cranio-encephalic traumas may also be factors that hasten neurovascular disturbances of the infundibulo-chiasmatic region, as is the case in other post-traumatic processes in which neurovascular action is universally accepted as the pathogeny.

It is our opinion, in agreement with Taptas and Dimopoulos,[26] that neurovascular disturbance is a perfect explanation for the anatomical lesions and symptomatology of opto-chiasmatic arachnoiditis. The different etiologies mentioned by various authors as true causes of these circumscribed leptomeningitides are simply non-specific factors in the onset of the disorder.

Many authors consider liberation of the chiasm and the optic nerves by means of a frontal craniotomy, similar to that performed for operations on the hypophysis, to be the most convenient therapeutic procedure in cases of opto-chiasmatic arachnoiditis. Statistics are not encouraging in this respect, as the operation was not successful in 72 per cent of a total 148 cases of the Neurological Service of the Pitié Hospital.[17]

Our figures are based on the study of 47 patients operated upon in the Department of Neurosurgery of the Post-Graduate Municipal School of Surgery of the Rawson Hospital, in the Institute of Neurosurgery of the Buenos Aires Faculty of Medical Sciences and in the Ophthalmological Hospital. Postoperative results may be considered unsuccessful in 63 per cent of these cases. We believe that true therapy should aim primarily at the functional condition of the disease, endeavouring to obtain a modification of those factors that cause the neurovascular lesion, which is the real substratum of arachnoiditis of the opto-chiasmatic region.

Different medications have been prescribed in this stage. Barbiturates, parasympathetic tonics, nicotinic acid, vitamin therapy, testosterone propionate, have been administered because of the favourable modifying action they have on neurovascular disturbances. Some authors consider male sexual hormonotherapy a "true medicine of the vascular wall."

Surgical treatment of the opto-chiasmatic region may be of use. It has a precise indication only when the arachnoiditic process has already set in. The accompanying mechanical factor can be of importance. Liberation of the optic tracts from the surrounding and imprisoning leptomeningeal membranes is at times beneficial or, if not, arrests the optic atrophy.

Undoubtedly, a better knowledge of the causes determining and favouring arachnoiditic lesions at the site of the optic nerves and chiasm will lead to the cure or modification of the neurovascular disturbance, before the mechanical factor, represented by the leptomeningeal formations, makes an opto-chiasmatic exploration necessary.

## RESULTS OF OPERATION FOR OPTO-CHIASMATIC ARACHNOIDITIS

Operations have been performed in 47 cases from 1933 to March 1950. Of these, 25 cases are from the Institute of Neurosurgery, directed by Prof.

E. Carillo. Patients operated upon by Prof. Balado are included in this group. Twelve are from the Service of Neurosurgery of the Santa Lucía Ophthalmological Hospital, directed by Prof. M. Oribe. Several of these patients were also operated upon by Prof. Balado. Ten cases are from the Department of Neurosurgery of the Post-Graduate Municipal School of Surgery of the Rawson Hospital.

Postoperative follow-up data, including fields of vision, fundus oculi, and visual acuity, were obtained in 19 cases (Inst. of Neurosurgery, 8; Ophth. Hosp., 4; Rawson Hosp., 7).

*Number of patients operated upon:* 47.
*Sex:* Male, 36; female, 11.
*Age of patients at time of operation:*

| *Years* | *No. of Cases* |
|---|---|
| 1–5 | – |
| 6–10 | – |
| 11–15 | 5 |
| 16–20 | 5 |
| 21–30 | 9 |
| 31–40 | 7 |
| 41–50 | 15 |
| 51–60 | 4 |
| over 61 | 1 |
| data missing | 1 |
| Total | 47 |

*Operative mortality:* 1 case (2 per cent).
*Postoperative results:*

| | | |
|---|---|---|
| Improved | 6 | = 37 per cent |
| Stationary | 1 | |
| Aggravated | 12 | = 63 per cent |

*Time interval between operation and last ophthalmological follow-up:*

| *Years* | *No. of Cases* |
|---|---|
| 0–1 | 3 |
| 1–2 | 2 |
| 2–3 | 1 |
| 3–4 | 1 |
| 4–5 | 2 |
| 5–6 | 2 |
| 6–7 | 2 |
| 7–8 | 1 |
| 8–9 | – |
| 9–10 | 3 |
| 10–11 | 1 |
| 11–12 | 1 |

*Time interval between onset of symptoms and operation in those cases in which operation was of benefit:*

| *Years* | *No. of Cases* |
|---|---|
| under 1 | 1 |
| 1–2 | 1 |
| 2–3 | 2 |
| 3–4 | 1 |
| 4–5 | 2 |

*Radiotherapy.* Four patients received immediate postoperative radiotherapy, and 3 received late postoperative radiotherapy. Results as regards vision of those patients receiving immediate postoperative radiotherapy over the opto-chiasmatic region can be considered improved in 3 cases and stationary in 1. The 3 patients receiving late postoperative radiotherapy showed no improvement.

The above results lead us to believe that immediate postoperative radiotherapy is of benefit and should be prescribed systematically.

## CONCLUSIONS

1) Treatment of opto-chiasmatic arachnoiditis should be immediate and should aim at the correction of the predisposing condition and the modification of the factors in the onset of the neurovascular process which is the actual cause of the formation of exudative, adhesive and membranous leptomeningeal lesions.

2) Operation is of benefit, once the opto-chiasmatic formations have set in, because of the mechanical liberation of the optic nerves and chiasm. Surgical exploration can produce favourable modifications in the neurovascular condition of the region.

Infiltrations of the cervicothoracic sympathetic nerve, if carried out at an early date, can be of benefit in modifying the neurovascular condition.

## SUMMARY

The study of 47 patients operated upon for opto-chiasmatic arachnoiditis is reported. Postoperative follow-up was obtained in 19 cases (fields of vision, fundus oculi, visual acuity).

The ideal treatment consists in immediate action to combat the predisposing condition and factors in the onset of the neurovascular affection, which constitutes the substratum of the inflammatory leptomeningeal reaction.

The operation can be of benefit, when the opto-chiasmatic lesions have set in, by liberating the optic nerves and chiasm.

In 63 per cent of the cases postoperative results are considered unsuccessful.

In the rest of the cases, that is in 37 per cent, the operation has brought about a variable degree of improvement or an arrest of the process.

## REFERENCES


1. Alajouanine, T., and Thurel, R. Arachnoidite opto-chiasmatique avec distension du lac basilaire et agrandissement de la selle turcique. *Rev. neurol.*, 1944, *76:* 296–298.
2. Arce, J. L'arachnoidite optochiasmatique (syndrome de Balado). *Bull. Acad. Méd. Paris*, 1934, 3 s. *111:* 106–112.
3. Balado, M. Una cuestión de prioridad. La arachoiditis óptico-quiasmática y la XIII Reunión Neurológica Internacional. *Sem. méd., Paris*, 1933, *2:* 1790–1794.
4. Balado, M. Rol de la tuberculosis en la producción de la aracnoiditis cerebro espinal. *Rev. Asoc. méd. argent.*, 1934. *48:* 1291–1293.
5. Balado, M., and Franke, E. Alteraciones quiasmáticas en la aracnoiditis del quiasma. *Arch. argent. Neurol.*, 1937, *16:* 119–126. Also: *Arch Oftal. B. Aires*, 1937, *12:* 618–625.
6. Balado, M., and Malbran, J. Atrofias ópticas de índole quirúrgica. Su tratamiento. *Arch. argent. Neurol.*, 1935, *13:* 90–120.
7. Balado, M., and Oribe, M. F. La encefalografía en el diagnóstico de las lesiones quiasmáticas e hipofisarias. *Arch. Oftal. B. Aires*, 1940, *15:* 377–399.
8. Balado, M., and Satanowsky, P. Tratamiento quirúrgico de la atrofia de la papila. *Arch. argent. Neurol.*, 1929, *4:* 71-75.
9. Barré, J. A., and Masson, J. Sur l'arachnoidite opto-chiasmatique. (Remarques à propos de plusieurs cas personnels.) *Rev. Oto-Neuro-Ophtal.*, 1936, *14:* 739–748.
10. Bollack, J., David, M., and Puech, P. Les arachnoidites opto-chiasmatiques. Étude ophtalmologique et neuro-chirurgicale. *Paris: Masson & Cie*, 1937, 300 pp.
11. Bruetsch, W. L. Etiology of optochiasmatic arachnoiditis. *Arch. Neurol. Psychiat., Chicago*, 1948, *59:* 215–228.
12. Carrillo, R. Imagen yodoventriculográfica de las aracnoiditis quiasmáticas. *Sem. méd., Paris*, 1936, *43:* 1674–1681.
13. Cushing, H. The chiasmal syndrome of primary optic atrophy and bitemporal field defects in adult patients with a normal sella turcica. *Trans. 13th Int. ophthal. Congr., Amsterdam*, 1929, 97–184.
14. Cushing, H. The chiasmal syndrome. *Arch. Ophthal., N.Y.*, 1930, *3:* 505–551; 704–735.
15. Davis, L., and Haven, H. A. A clinico-pathologic study of the intracranial arachnoid membrane. *J. nerv. ment. Dis.*, 1931, *73:* 129–143; 286–300.
16. Dickmann, G. H., Damel, C. S., and Just Tiscornia, B. Consideraciones a propósito de 5 casos de leptomeningitis optoquiasmática. *Arch. Oftal. B. Aires*, 1943, *18:* 481–495.
17. Feld, M., and Auvert. Conclusions à l'étude d'une statistique de 148 cas d'arachnoïdite opto-chiasmatique opérés. *Rev. Oto-Neuro-Ophtal.*, 1947, *19:* 315–320.
18. Frazier, C. H. Cerebral pseudotumors. *Arch. Neurol. Psychiat., Chicago*, 1930, *24:* 1117–1132.
19. Malbran, J. Una prueba más del polimorfismo perimétrico de las aracnoiditis optoquiasmáticas. *Arch. Oftal. B. Aires*, 1935, *10:* 632–636.
20. Malbran, J., and Balado, M. Aracnoiditis quiasmática. *Arch. argent. Neurol.*, 1933, *8:* 96–106.
21. Martel, T., and Guillaume, J. Les arachnoïdites opto-chiasmatiques. *Rev. méd., franç.*, 1935, *16:* 291–296.
22. Matera, R. F. Signos yodoventrículográficos en las aracnoiditis encefálicas. Etiología, anatomía patológica, patogenia, sintomatología y clasificación de las aracnoidits. *Buenos Aires: El Ateneo*, 1946, 68 pp.
23. Morea, R. Tratamiento quirúrgico de la atrofia de la papila. *Arch. argent. Neurol.*, 1933, *7:* 302–333.
24. Puech, P., David, M., and Brun, M. Contribution à l'étude des arachnoïdites opto-chiasmatiques. *Rev. Oto-Neuro-Ophtal.*, 1933, *11:* 641–649.
25. Rubino, A. Patologia e clinica della regione diencefalo-chiasmatico-ipofisaria, con particolare riguardo alla sintomatología oculare. *Milán: Cedam*, 1937, 242 pp.
26. Taptas, J. N., and Dimopoulos, T. Arachnoïdites opto-chiasmatiques et maladie neurovasculaire. *Paris: Masson & Cie*, 1949, 110 pp.
27. Thurel, R. Arachnoïdite optochiasmatique. Rôle de la distension du lac basilaire. *Bull. Soc. Ophtal. Paris*, 1948, *19:* 276–284.
28. Vincent, C., Puech, P., and David, M. A propos de sept cas d'arachnoïdite opto-chiasmatique. *Rev. neurol.*, 1931, *55:*760–767.

# A SYNDROME IN ACUTE CERVICAL SPINE INJURIES FOR WHICH EARLY OPERATION IS INDICATED

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IN ACUTE cervical spine injuries an immediate complete paralysis with hypesthesia at the level of the lesion and an associated sparing of touch and some vibration sense is a syndrome for which early operative intervention is indicated. Two cases are presented here in which a diagnosis of acute extruded nucleus pulposus was made preoperatively on the basis of the syndrome, and the lesion was confirmed at operation. It is hoped that a discussion of these cases may lead to an earlier recognition of these lesions with the prevention or diminution of residual neurological disability.

The production of this syndrome may be explained on a precise anatomical basis. In May, 1947 Kahn[5] presented a paper which first described the role of the dentate ligaments in chronic anterior spinal cord compression by a posteriorly protruded cervical nucleus pulposus. In these cases the symptoms of spasticity, hyperreflexia, disturbance of gait, and modified sensory changes simulate a degenerative lesion of the cord, such as lateral sclerosis. Previously it was believed that these symptoms were on the basis of compression of the anterior spinal artery. However, Kahn has indicated that the spinal cord may be firmly fixed by the fragile-appearing, but remarkably strong dentate ligaments so that posterior displacement of a herniated disk causes paralysis by anterior cord compression with exertion of stress upon the cord just above the attachment of the dentate ligaments. The publishers have very kindly permitted me to reprint Fig. 1 from the original article which shows these lines of stress (Fig. 1). I would like to quote from this article: "In anterior spinal cord compression I believe that, with pressure over a period of time, the pyramidal tracts, because of the greater stress on them and the large size of their fibers, have more disturbance of conductivity than the pain fibers of the spinothalamic tracts, even though the latter are closer to the compressing mass, be it midline herniated nucleus pulposus or tumor. Touch is preserved because, even though the touch fibers of the ventral spinothalamic tracts may fail to conduct, there is still sufficient sensation carried in the more protected posterior columns to prevent the clinical detection of touch disturbance. Postural sense is preserved because the attachment of the dentate ligaments prevents the posterior columns, which are farthest from the compressing mass, from being pressed against the unyielding laminae."

Bucy, Heimburger, and Oberhill[2] in their article on compression of the

cervical cord by herniated disks are inclined to accept Kahn's mechanical stress concept as the cause of symptoms rather than the theory of possible compression of the anterior spinal artery.

In both of these articles the authors have presented cases in detail that demonstrate the insidious pathogenesis of this type of lesion which simulates chronic degeneration of the cord. It should be emphasized that in these chronic cases there is a gradual development of symptoms, but in the acute

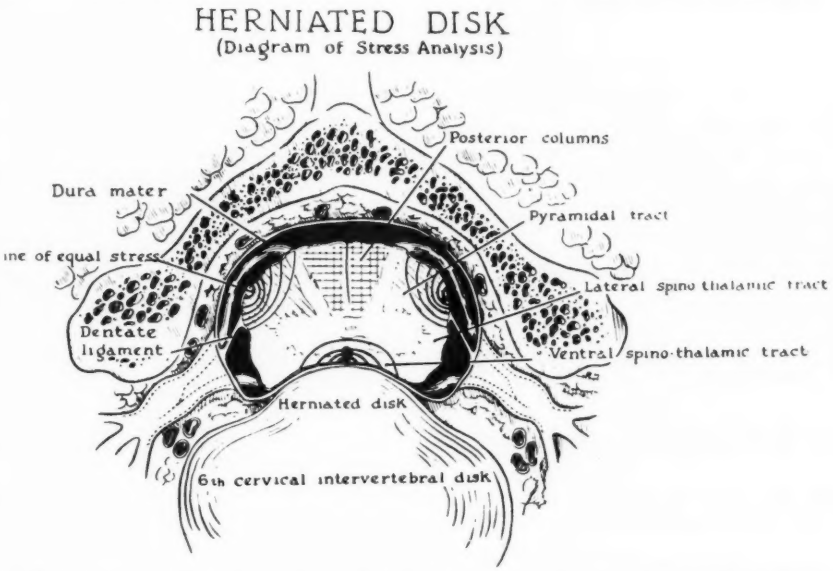


FIG. 1. "Showing lines of stress in anterior spinal cord compression. Greatest stress is anterior on tracts disturbance of which would not be demonstrable by clinical tests. Secondary stress is directly on pyramidal tracts. The leg area is most lateral in pyramidal tracts, while the hand area is most medial, explaining usual sparing of the hands." (*Reprinted by courtesy of Dr. E. A. Kahn.*[5])

cervical spine injury there is an immediate appearance of the syndrome. Nevertheless, the author is inclined to believe that the same mechanical stress factor is of fundamental importance in both the chronic and the acute types and feels that the following 2 cases illustrate that point.

*Case 1.* J.S., 36 years, white male, was involved in an auto accident on Aug. 21, 1948, and was thrown from his truck and pinned to the ground under it. He recalls lying beneath the truck, numb from the neck downward, and was unable to move either lower extremity. He was given first aid treatment at the local hospital and on the following day was transferred to St. Luke's Hospital, Cleveland, Ohio.

*Examination.* The patient had point tenderness over the lower cervical spine, weakness in his grip, paralysis of both lower extremities, and a level of hypesthesia at the C7 dermatome. However, there was no apparent loss of touch. There was abdominal distention, with urinary retention, priapism, and complete areflexia.

No pathological reflexes were observed. Routine roentgenograms of the cervical spine showed no evidence of fracture or dislocation. On August 24 the neurosurgical consultant performed a careful cervical myelogram which revealed no evidence of block or distortion of the pantopaque under fluoroscopy. However, the head could not be adequately hyperextended to pool the contrast medium properly for fear of causing further cord damage. On August 25, the level of hypesthesia persisted at the C7 dermatome with the preservation of touch. There was diminution of vibration sense, with slight weakness in extension of arms at the elbows, some impairment of the grip, and paralysis of the lower extremity bilaterally. Because of the neurological signs a diagnosis of herniated nucleus pulposus at the 6th and 7th cervical interspace was made in spite of the negative but somewhat inadequate myelogram.

*Course.* On August 26 Crutchfield tongs were inserted to insure immobilization of the spine, and the patient was placed on a Stryker frame in order to provide better nursing care. After 3 days there was a slight drop in the sensory level from the C7 dermatome bilaterally to the D5 dermatome on the left and the D7 on the right. The grip in both hands appeared slightly improved, but there was no change in the motor status of the lower extremities. On September 2 there was regression of the sensory level to the C7 dermatome with the same degree of impairment of motor power as at the time of admission. The diagnosis of herniated nucleus pulposus was again suggested.

*Operation.* Laminectomy of the 5th, 6th, and 7th cervical vertebrae was performed 11 days after injury. A simple linear fracture without depression was found in the lamina of the 6th cervical vertebra bilaterally and in the left lamina of the 7th. There was no displacement of the vertebral bodies, but a brownish discoloration of the dura was observed suggesting a minimal amount of old hemorrhage. The dura was incised in the mid-line and the arachnoid cut laterally. The dentate ligaments, which were taut, were sectioned bilaterally at three points, and upon retracting the cord medially and cutting the anterior surface of the dura a freely lying, fragmented nucleus pulposus was found extruded at the 6th and 7th interspace (Fig. 2). These fragments were removed with the aid of an incision made in the dura anteriorly on the opposite side of the canal and the interspace was thoroughly curetted bilaterally to remove any other loose tissue. The cord was of average consistency and showed no evidence of trauma or degeneration. Since there was no swelling of the cord after removal of the disk, the dura could be closed, and the remainder of the wound was sutured in layers.

*Course.* Eleven days postoperatively the patient began to move his legs and in another week began to recover some bladder control. On October 13 the Crutchfield tongs were removed, a plaster collar was applied, and the patient was removed from the Stryker frame. On November 12 he was transferred to Crile Veterans Hospital, Parma, Ohio for convalescent care, and with good physiotherapy he gradually improved.

On Aug. 11, 1950, approximately 2 years after his injury, the patient presented the pattern of a modified Brown-Séquard syndrome. There was good strength in the right extremities, but there was weakness in the flexors and lateral interossei of the left hand and in all movements of the left lower extremity, particularly in plantar flexion and dorsiflexion of the left foot. Hypesthesia persisted on the right from the L2 through the S5 segment; otherwise there was no abnormality in any sensory modality. The abdominal and cremasteric reflexes were normal on the right,

but absent on the left. Bilateral pyramidal tract signs were observed in the upper and lower extremities, markedly positive on the left and minimal on the right. Bladder control was good except in the morning when there was some urgency. Constipation was controlled by catharsis. The patient wore a low kick-up spring brace for his partial left foot drop and was able to get about for short distances without support. Most of the time he carried a cane which aided him in maintaining balance. The patient is a nurseryman and stated that he could supervise the care of his sixty-four acres, although he does tire easily. He assured the author that he is still continuing to improve from month to month even at this late date.

FIG. 2. *Case 1.* The 7th, 6th and 5th cervical nerve roots are exposed, and an extruded nucleus pulposus (arrow) is seen protruding through an incision in the anterior surface of the dura between the 6th and 7th nerve roots.

*Comment.* It is believed that the symptoms in this acute case may be explained on the same basis as the chronic cases of protruded nucleus pulposus described by Kahn,[5] and by Bucy *et al.*[2] On lumbar puncture there was no block and when pantopaque was introduced it passed rapidly upward through the cervical region without being sufficiently pooled to give a satisfactory visualization of the area; so the diagnosis of extruded nucleus pulposus was made preoperatively on the basis of neurological signs alone. It is our feeling that this patient should have been operated upon sooner and perhaps his convalescence and recovery would have been more rapid and complete. As a result of this experience we were on the alert for any case that presented a similar neurological pattern.

*Case 2.* R.C., 21 years, white male, a college football player, charged into the line during a game on Nov. 13, 1948, and suffered an injury to his cervical spine. The patient stated that he had immediate numbness from his neck on downward, including his hands. He could move his upper arms, but had paralysis of his hands, trunk, and lower extremities. He was transferred to Crile Veterans Hospital, Parma, Ohio on the evening of his injury.

*Examination.* There was hypesthesia at the level of the C6 dermatome bilaterally. Touch was preserved over the entire body, but there was a loss of approximately fifty per cent of vibration sense. There was complete areflexia, with paralysis of lower extremities, and inability to extend the arm at the forearm and to flex and extend the fingers of both hands. Roentgenograms of the cervical spine showed a severe compression fracture of the 5th cervical vertebra with some displacement of the body posteriorly (Fig. 3). The anterior-posterior view showed no abnormality. The neurosurgical resident reported the neurological and roentgenographic findings by telephone, and it was suggested to him that the slight posterior displacement of the body of the vertebra could cause the symptoms, but that a herniated disk at the 5th and 6th interspace could not be excluded as a possibility. On lumbar puncture the CSF was under normal pressure, clear and colorless, with no evidence of block on the Queckenstedt test. A myelogram was regarded as inadvisable for fear of causing further damage to the cervical cord. Crutchfield tongs were applied to steady the head and apply traction.

FIG. 3. *Case 2.* Lateral X-ray showing compression fracture of the body of the 5th cervical vertebra and slight posterior displacement of the body.

*Operation.* About 20 hours after injury a laminectomy of the 4th, 5th and 6th cervical laminae was performed. There was a depressed fracture of the 5th cervical lamina bilaterally with about 4 mm. depression on the right side, but apparently there was little or no compression of the dura and cord. The dura was opened in the mid-line and the arachnoid incised laterally. The cord was of average consistency without evidence of contusion, but was displaced posteriorly. The dentate ligaments were extremely taut. Upon sectioning three ligaments bilaterally the cord could be retracted to either side readily. When the dura was incised anteriorly to the left of the cord, an extruded disk was found lying fragmented in the canal with several pieces of bone attached. A slightly elevated bony ridge was also observed posteriorly. The interspace was thoroughly curetted in order to remove all loose tissue. A No. 10 rubber catheter was lubricated and then passed in either direction in the subarachnoid space without encountering any resistance, and the spinal fluid flowed freely. The arachnoid covered the cord

n the mid-line, and the dura was left open in order to prevent constriction of the ord. Gelfoam was placed over the aperture in the dura and the wound closed in ayers. The patient was then replaced upon the Stryker frame in traction.

*Course.* There was gradual improvement so that by Dec. 7, 1948 slight voluntary novement was present in the lower extremities. On Jan. 17, 1949 tidal drainage ould be discontinued, and by April 1949 the patient could walk a short distance vithout support. On Aug. 11, 1950, 21 months after injury, the patient was able o drive fifty miles alone to keep the appointment for the examination. There was ıypesthesia to the level of the D7 dermatome on the right, but otherwise there was ıo sensory impairment in any modality bilaterally. Some weakness was found in he interossei of the right hand, in the grip of the right hand, and all movements of he right lower extremity. The abdominal and cremasteric reflexes were absent bi-aterally. There was some increase in tonus of the lower extremities. A prominent Hoffmann reflex was observed on the right with only a slight response on the left. Marked bilateral Babinski signs were obtained. The patient walked well with double ıpright braces, but the right lower extremity was weak, and his partial foot drop was omewhat incapacitating. He could walk on flat ground without aid, but still felt nsecure without his cane and braces. The bladder status was satisfactory except or some urgency and dribbling in the early morning. The patient has been able to arry out a program of 24 semester credit hours of study during the past year and was graduated from college as an education major. He plans to continue with his areer of physical education instructor and stated that he was still noting consider-ıble improvement in his condition even from one week to the next.

*Comment.* Because of the experience with the first case the diagnosis of a ruptured nucleus pulposus was immediately suspected, and as a result the second patient was operated upon as an emergency. The latter had a more rapid recovery. Perhaps the injury was less severe with a slighter contusion to the cord, although the x-ray showed much more bony damage, but earlier operation may also have played an important part in the recovery.

## DISCUSSION

The treatment of cervical spine injuries with cord involvement has been, and still is, one of the most controversial topics in neurosurgery.[1,4,6–12,14] The percentage of salvage in this group of patients is not great, but there must be an active approach to the problem if there is to be any hope of improving our morbidity. A cervical cord injury ought to be regarded as an acute surgical emergency. The patient should be examined early, and, if proper indications are present, should be operated upon immediately. The cord does not tolerate acute compression for any length of time, because edema, anoxia, and irreversible changes soon occur.

In the past in cervical cord injuries attention has been paid to the spine and cord, but there have been relatively few observations on acutely herniated disks or on taut dentate ligaments. The author believes these factors may play an important part in the production of symptoms and the ultimate prognosis in certain cases.

There is, of course, practically universal agreement that a patient with

an immediate complete lesion, both sensory and motor, without a block on Queckenstedt test, should not be subjected to operation unless an attempt is being made to achieve a more satisfactory alignment of the spine. In the latter situation, this is of an elective rather than an emergency nature.

A year ago the author[13] published a paper on herniated disk with immediate complete paralysis, and listed 5 indications for early operation in acute spine injuries:

1. A history of progression of neurological signs.
2. Compound fractures of the spine, particularly those patients with spinal fluid leaks.
3. Marked encroachment of bony fragments upon the spinal canal as exhibited in the roentgenograms.
4. With a lumbar puncture needle in place, evidence of complete blockage of the spinal fluid on jugular compression.
5. Evidence of blockage of a column of pantopaque upon myelogram examination in those cases which, in spite of a negative Queckenstedt test, have a definite sensory level.

As a result of the study of the 2 cases presented in this article it is believed a 6th indication should be added to the list:

6. Immediate complete paralysis with hypesthesia to the level of the lesion, but preservation of touch throughout the body.

Critics of the 6th point might maintain that since the lesion in these cases was an incomplete one, the patients would have recovered on a conservative regime. However, when one reviews the cases presented in the literature one is struck by the disabling residual neurological symptoms resulting from chronically protruded disks. To prevent this, the disk should be removed in the acute phase when it is fragmented and before calcification has occurred, for the latter frequently makes removal of this structure an impossibility. A fracture dislocation, with slight posterior displacement of the vertebral body, or possibly even a marked edema of the cord anteriorly from the recoil[3] of a rebound disk, apparently can cause sufficient anterior compression of the cord for the development of the syndrome which has been described. This condition may be treated by aligning the spine with traction and then decompressing the cord by laminectomy, incising the dura, and sectioning the dentate ligaments bilaterally at three or four points.

## SUMMARY

Two cases of acute cervical spine injury are presented in which a syndrome is described consisting of immediate complete paralysis with hypesthesia at the level of the lesion, but with preservation of touch and the retention of part of vibration sense. A ruptured nucleus pulposus was diagnosed preoperatively in both instances and found at operation, although this was in conjunction with a compression fracture of the cervical body in the second case.

The mechanical stress concept first described by Kahn in his presentation of the role of the dentate ligaments in chronic anterior cord compression is the basis on which it is believed the symptoms in these 2 cases may be explained.

The indications for early operation on cervical cord injuries are listed and the acute dentate ligament syndrome described herein is included as an additional criterion for early operative intervention.

The author wishes to thank Dr. Wallace Duncan, Section of Orthopedic Surgery, St. Luke's Hospital, Cleveland, Ohio, for the opportunity of treating the first patient. He also wishes to express his appreciation to Dr. Claude Beck, Senior Neurosurgical Consultant, Crile Veterans Hospital, Parma, Ohio, for the privilege of presenting the above cases, both of which were eventually treated on his service.

## REFERENCES

1. Baker, G. S., and Daniels, F., Jr. Concussion of the spinal cord in battle casualties. *J. Neurosurg.* 1946, *3:* 206–211.
2. Bucy, P. C., Heimburger, R. F., and Oberhill, H. R. Compression of the cervical spinal cord by herniated intervertebral discs. *J. Neurosurg.*, 1948, *5:* 471–492.
3. Cramer, F., and McGowan, F. J. The rôle of the nucleus pulposus in the pathogenesis of so called "recoil" injuries of the spinal cord. *Surg. Gynec. Obstet.*, 1944, *79:* 516–521.
4. Elsberg, C. A. Fractures of the spine and their treatment, amount of disability, and indications for and results of operative interference. *Bull. U. S. Bureau of Labor Statistics*, No. 485, 1928, 93–101.
5. Kahn, E. A. The rôle of the dentate ligaments in spinal cord compression and the syndrome of lateral sclerosis. *J. Neurosurg.*, 1947, *4:* 191–199.
6. Kristoff, F. V., and Odom, G. L. Ruptured intervertebral disk in the cervical region. A report of twenty cases. *Arch. Surg., Chicago*, 1947, *54:* 287–304.
7. McCravey, A. A plea for exploration of spinal cord and cauda equina injuries. *J. Amer. med. Ass.*, 1945, *129:* 152–153.
8. Matson, D. D. Treatment of compound spine injuries in forward army hospitals. *J. Neurosurg.*, 1946, *3:* 114–119.
9. Mayfield, F. H., and Cazan, G. M. Spinal cord injuries. Analysis of six cases showing subarachnoid block. *Amer. J. Surg.*, 1942, n.s. *55:* 317–323.
10. Munro, D. Cervical-cord injuries. A study of 101 cases. *New Engl. J. Med.*, 1943, *229:* 919–933.
11. Pilcher, C. Injuries of spinal cord and cauda equina. *South. Surg.*, 1942, *11:* 755–764.
12. Raaf, J. Treatment of the patient with spinal cord injury. *Amer. J. Surg.*, 1945, n.s. *67:* 263–275.
13. Schneider, R. C. Acute traumatic posterior dislocation of an intervertebral disc with paralysis. *J. Bone Jt. Surg.*, 1949, *31-A*, 566–570.
14. Taylor, A. S. Fracture dislocation of the cervical spine. *Ann. Surg.*, 1929, *90:* 321–340.

# THE DIAGNOSIS OF TRAUMATIC INTRACRANIAL HEMORRHAGE BY ANGIOGRAPHY*

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THE diagnosis of massive intracranial bleeding in the seriously injured patient is sometimes difficult, and exploratory multiple trephine openings and diagnostic air studies may be dangerous and inconclusive. Since patients in this group may have diffuse brain damage with contusions and non-surgical hemorrhagic collections, accurate localization of the lesion and estimation of its dimensions have importance. Such a diagnostic procedure may be angiography. Although its use is not without danger, a successful angiogram accurately may locate a massive lesion and also differentiate between subdural, epidural and intracerebral hematomas.

The patients included in this study were from the neurosurgical services of the Detroit Receiving and Grace Hospitals over a period of 6 months (January to June 1950). Approximately 350 head injury patients are admitted during this period. Of these, 45 per cent or 160 have major cranial injuries consisting of fracture of the skull and brain contusions and laceration with or without fracture.

Angiography was employed in those patients with major cranial injuries who either did not improve under conservative management or who presented evidence of a "dynamic syndrome" of increasing stupor, new focal signs, and cardiac, thermal, or respiratory evidence of progressive cerebral dysfunction. Thirty arteriographic studies were made.

Under local or pentothal anesthesia, a percutaneous angiogram was obtained by the injection of 35 per cent diodrast and satisfactory anteroposterior and lateral studies were made. Although to begin with, local anesthesia was used, most of the patients required additional pentothal administration. A routine survey set of roentgenograms was obtained at the same time. If a surgical lesion was demonstrated, the patient was removed to the operating room for treatment. All of the patients in groups A, B, C, G, and H were operated upon. In group F, all but 2 were trephined (Table 1).

## RESULTS

Table 1 summarizes the results of the angiographic studies of 30 patients. The mortality is also included. There were 9 subdural hematomas, 2 epidural hematomas, 4 temporal lobe intracerebral collections and 1 "extravasation" lesion, 2 aneurisms, and 10 cases in which there was no evidence of a complicating surgical lesion. It is of note that there was 1 false negative and

* Aided by the Kresge fund.

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TABLE 1

*Summary of results*
(30 cases)

| | No. | No. | Deaths |
|---|---|---|---|
| A. Subdural Hematoma | | 9 | |
| 1. Acute | 4 | | 3 |
| 2. Subacute | 3 | | 0 |
| 3. Chronic | 2 | | 1 |
| B. Epidural Hematoma | | 2 | 0 |
| C. Intracerebral Hematoma | | 4 | 3 |
| Etiology | | | |
| 1. Traumatic | 2 | | |
| 2. Primary vascular disease | 2 | | |
| D. Aneurisms | | 2 | 0 |
| E. Extravasation Phenomenon | | 1 | 0 |
| F. Brain Contusion with Normal Angiograms | | 10 | 3 |
| G. False Normal Angiogram | | | |
| Subdural hydroma bilateral | | 1 | 0 |
| H. False Positive Angiogram | | | |
| Severe diffuse temporal lobe contusion and laceration | | 1 | 1 |
| Total | | 30 | 11 |
| Total Mortality | | | 36.6% |

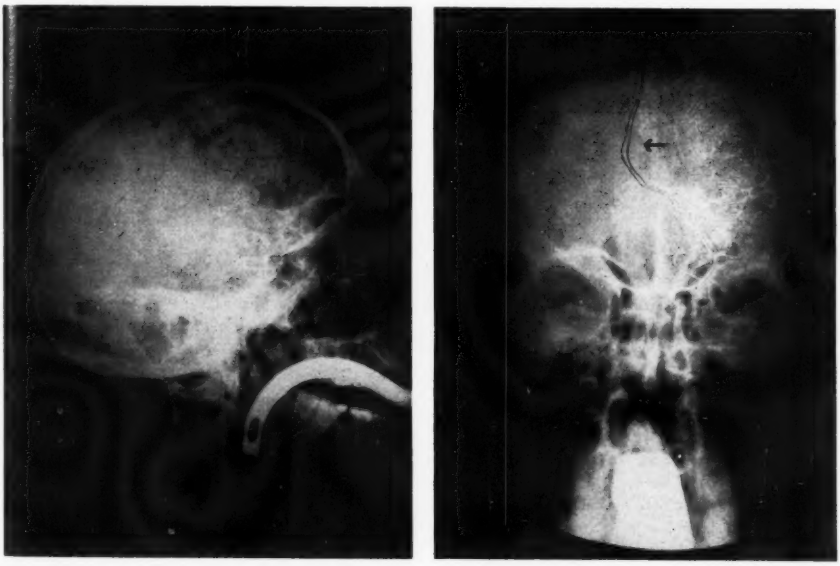

FIG. 1.* R.M., 23-year-old male, beaten in fight 10 days before operation. Was not unconscious, but became progressively stuporous. Had right frontal headache, vomiting, dizziness and diplopia. Admitted day before operation in semicomatose state. Had bruise about right eye with subconjunctival hemorrhage, left 3rd nerve palsy, ptosis of lid, fixed pupil, and bilateral Babinski reflexes. Roentgenograms normal. Collection outlined at periphery of brain. Anterior cerebral artery shifted. Liquid and solid subdural hematoma (150 cc.) evacuated. Lived.

* Illustrations have been retouched for clarity.

1 false positive angiogram. The former occurred in a profoundly injured patient who was found to have a bilateral subdural hydroma by burr openings. The latter occurred in a patient with severe damage to the temporal lobe (Fig. 8).

The patterns of typical *subdural hematoma* studies are shown in Figs. 1, 2 and 3. A marked shift of anterior cerebral to the opposite side is noted. The middle cerebral may be depressed. If the finer radicals of the middle cerebral are also visualized, the space occupied by the hematoma may be evaluated by the distance between the skull and cerebral surface vessels.

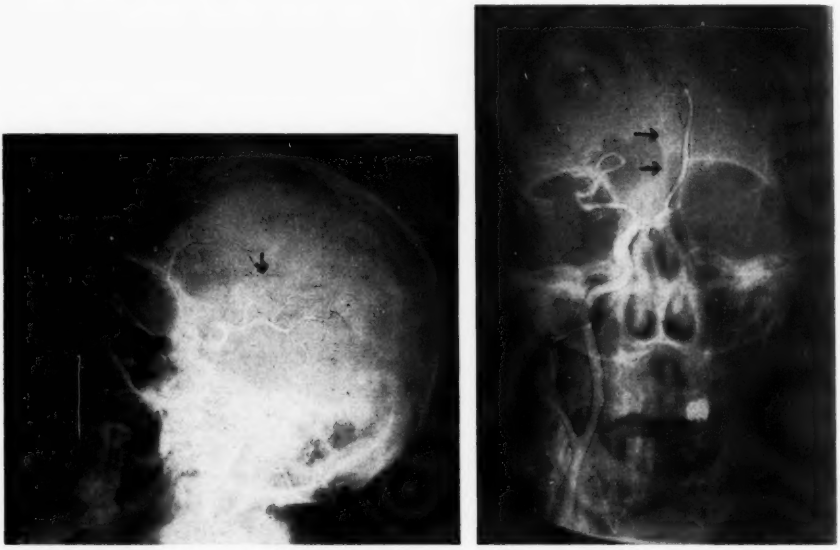

FIG. 2. W.D., 49-year-old male, fell in bathtub 13 days before admission, striking head. Was not unconscious. Nine days later lethargy developed with a short period of unconsciousness. At admission he was semiconscious. Right pupil was slightly larger than left. There was left facial weakness. Arteriogram revealed anterior cerebral artery displaced to left with depression of middle cerebral, indicating a subdural hematoma on the right side. Burr holes evacuated a large (150 cc. liquid) right frontotemporal subdural hematoma. Lived.

The pattern of the *intracerebral hematoma* of the temporal lobe is shown in Fig. 4. The anterior cerebral is shifted to the opposite side in part of its extent. In the lateral views, the Sylvian vessels are dislocated upward and forward.

In one of these patients, J. D., the fact that the angiogram pre-operatively localized a temporal lobe lesion accounted for his survival. Routine burr openings most probably would have revealed only the associated subdural extravasation. His critical state may then have been wrongly ascribed to non-surgical type of brain damage. This patient's findings were as follows:

J.D., a 50-year-old white male, was admitted on Feb. 6, 1950, having fallen and struck his head on a curb. He was uncooperative and confused, with evidence of alcoholism. A left Babinski reflex was the only abnormal neurologic sign. B.P. was 140/80. Roentgenograms of the skull showed a left occipital linear fracture measuring 3 inches. A calcified pineal gland was in normal position. An EEG at admission showed a severe right frontotemporal disturbance with a delta focus of 1.5–3/sec. waves. Spinal puncture yielded bloody CSF under normal pressure. The patient

FIG. 3. R.E., 32-year-old male, beaten in fight 2 months prior to trephine. Progressive disorientation with papilledema; roentgenograms normal; CSF clear. Arteriogram showed shift of anterior cerebral artery to the right with depression of left middle cerebral artery (note normal pattern of right side for comparison), typical of frontotemporal collection. Liquid hematoma (200 cc.) evacuated. Death.

improved although he remained confused. An EEG on Feb. 10, 1950 showed "improvement of the basic rhythm with the delta focus not so pronounced. Paroxysmal activity resembling psychomotor patterns are present in the right temporal area." Two days later, on Feb. 12, 1950, the patient became apathetic, then stuporous. His neurologic status rapidly changed, resulting in a dilatation of the right pupil and a left hemiparesis, with return of pyramidal tract signs. The fundi remained normal.

An angiogram was done, showing the pattern presented in Fig. 4. Operation followed. Exploratory burr openings were converted into use for a small temporal craniotomy flap, only when a pancake type of subdural hematoma was found covering the frontotemporal area. Incision of the temporal dura resulted in extrusion of an intracerebral hematoma, measuring about 100 cc.

The patient improved and was discharged on Feb. 23, 1950, without neurologic deficit. A final EEG on Feb. 20, 1950 showed "disappearance of the delta activity."

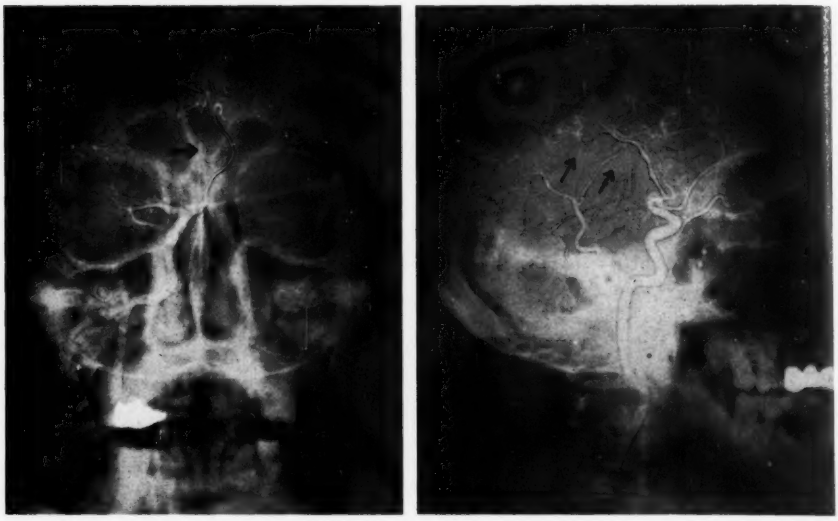

FIG. 4. E.B. Pattern of intracerebral hematoma similar to J.D. (see case report). Shift of anterior cerebral to left with elevation of Sylvian vessels. Evacuation of right temporal intracerebral collection by small bone flap. Considered a subdural suspect. A small subdural collection was present and the massive intracerebral clot evacuated might have been overlooked without angiogram.

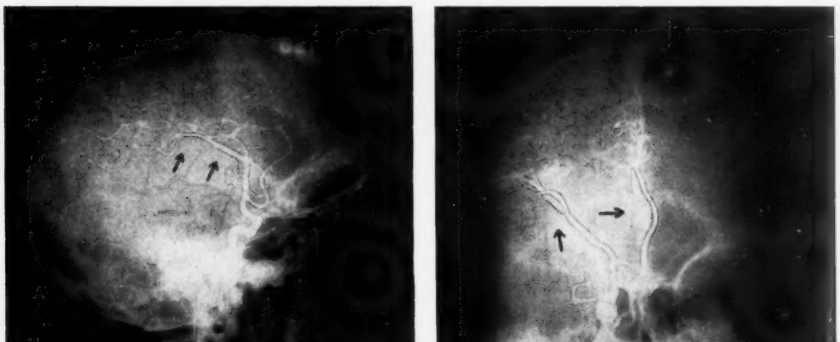

FIG. 5. C.W., 47-year-old male, struck on head 9 days before operation. Was briefly unconscious. Severe right frontal headache developed. Roentgenograms showed linear fracture in right parietotemporal area. Shortly after admission had dilated right pupil with ptosis and slight weakness of left arm. Angiogram showed upward displacement of middle cerebral and shift of anterior cerebral. Temporal epidural collection of 100 cc. of solid blood evacuated. Lived.

Examples of the findings in *epidural hematoma* are shown in Figs. 5 and 6. In Fig. 5 the shifted middle cerebral vessel suggests a temporal mass. In temporal lobe hematoma, the branches of the middle cerebral are more likely to be locally deformed in a direction upward and anteriorly. In Fig. 6 there is marked separation of the anterior and middle cerebral group of vessels. An intracerebral frontal lobe mass could also result in such a finding. In the case illustrated, there was a large frontal extradural hematoma.

Two patients were admitted in a semiconscious state attributed to head injuries, having fallen as the result of *aneurismal rupture* with subarachnoid

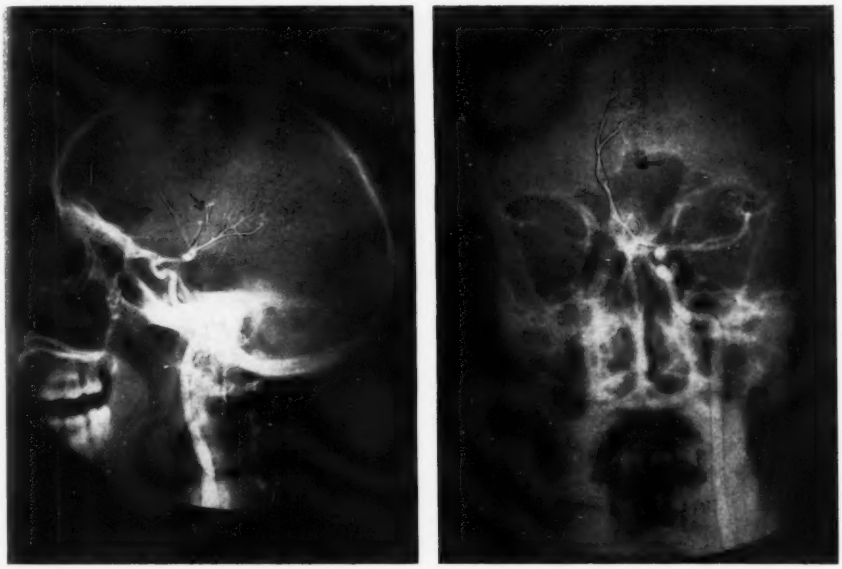

FIG. 6. C.S., 23-year-old male, struck on head with brick 24 hours before operation. Was not unconscious. Roentgen studies normal. CSF clear. Gradual stupor with right 7th nerve weakness. Angiogram showed flattening of anterior cerebral and shift to right. Frontal epidural collection (100 cc. solid) evacuated by frontal craniotomy. Lived.

hemorrhage. Both were considered subdural hematoma suspects, but angiograms revealed the correct diagnosis (Fig. 7).

Of interest also has been the occurrence of an "*extravasation phenomenon*," probably indicating cerebral contusion. A circumscribed area of diodrast extravasation was noted in 1 patient, unassociated with a subdural collection. This patient recovered. He had evidence of diffuse brain injury. This is an unusual finding in the diffusely damaged brain, even with fatal outcome, since the vascular pattern in the angiogram is usually normal.

In 2 instances, air studies gave false positive results (Fig. 8), while the angiograms were normal. Trephine of these patients confirmed the angiographic studies.

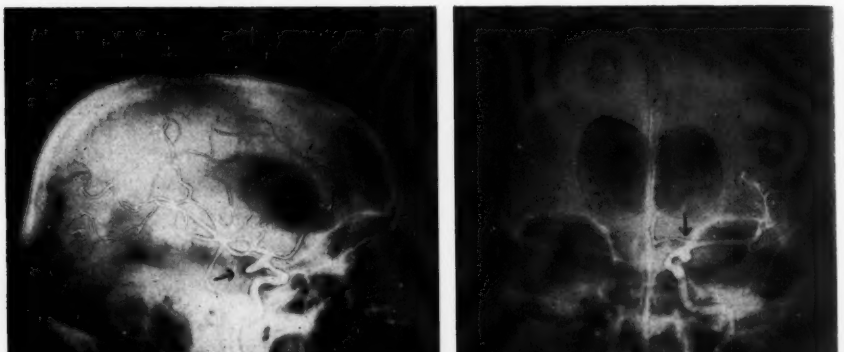

FIG. 7. V.J., 40-year-old female. On admission was conscious, confused, disoriented, aphasic, with right hemiparesis. Roentgenograms showed suggestive fracture of right squamosal suture and slight displacement of pineal to right. CSF xanthochromic. Considered as subdural hematoma suspect until angiograms revealed an aneurism, following air study. Lived.

FIG. 8. S.B., 57-year-old male, was struck by a car. Left occipital fracture, progressive deepening stupor with dilated right pupil and paresis of left lower extremity. Shift of anterior cerebral artery with upward displacement of middle cerebral artery. Death after exploration. Diffuse damage to temporal lobe with epidural, subdural and intracerebral collections not of surgical proportion. Classified as false positive angiogram.

## DISCUSSION

Many of the patients suspected of subdural hematoma were trephined in spite of normal vascular patterns in the angiogram. In but 1 instance, in which a hydroma occurred, did the angiogram fail to reveal a surgical type of lesion, if present. Autopsy studies also verified this accuracy. An important exception must be made with a subdural or epidural collection in the parietal or occipital area or, of course, in the posterior fossa. Such a lesion is uncommon and was not encountered in this group of patients. If doubt exists that such a lesion is present, posterior exploratory openings must be made with or without an air study.

The arteriogram is valuable in distinguishing temporal lobe intracerebral hematoma. Pre-operative knowledge that a massive collection exists avoids misjudging the significance of a coincidental subdural collection. A small temporal flap can be planned and the hematoma evacuated.

It is of note that the pattern for the epidural hemorrhage in temporal region is similar to that of the temporal lobe hematoma, but with the former, the trunk of the middle cerebral is more apt to be dislocated upward; whereas, with a temporal hematoma, a dislocation of the middle cerebral branches upward and forward is usually the case. The presence of a temporal skull fracture also may be evidence in favor of the epidural collection. Often the classical clinical syndrome clearly distinguishing middle meningeal hemorrhage is absent; consequently, a diagnostic procedure accurately delineating the lesion may be useful.

The shifted anterior cerebral artery indicates the presence and side of the hematoma. In large unilateral subdural hematomas, the entire vessel is shifted to the opposite side. The depressed or elevated Sylvian vessels may distinguish the subdural from an epidural or intracerebral clot. A surface collection may be outlined by the vascular compression—its size well estimated.

Unfortunately, there is a disadvantage in moving the patient for the roentgen studies. There is a further additional risk when pentothal anesthesia is necessary for the uncooperative patient. The time consumed in doing the arteriogram is a consideration. The question must be raised whether these risks are warranted in the interest of prompt and accurate diagnosis. The conventional use of multiple exploratory burr openings under local or general anesthesia with or without the injection of air and ventriculography also have disadvantages and may lead to inaccurate localization. Arteriography appears to be useful and more experience will give it its proper place among the diagnostic procedures in the better management of the seriously ill patients following head trauma.

## SUMMARY

1. Angiographic studies were made in a group of 30 seriously ill patients with head injury, suspected of massive intracranial hemorrhage.

2. Typical vascular patterns were found to distinguish the subdural, epidural and intracerebral hematomas.

3. Angiography was found to be reliable. The procedure is superior to the more complicated and possibly inaccurate "exploratory trephine."

4. There are several risks involved, chiefly related to anesthesia in head injury patients.

## REFERENCE

1. KRISTIANSEN, K. Cerebral angiography in the diagnosis of intracranial hematomas. *Surgery*, 1948, *24*: 755–768.

# FIBROUS DYSPLASIA OF THE SKULL

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## GENERAL ASPECTS OF FIBROUS DYSPLASIA

WITHIN recent years, largely as a result of the contributions of Albright and his associates,[2,4] of McCune and Bruch,[34] Lichtenstein,[31] and of Lichtenstein and Jaffe,[32] the concept of fibrous dysplasia of bone as a disease entity has become established. The clinical features of this disorder were clearly epitomized in the subtitle of a paper published by Lichtenstein and Jaffe[32] in 1942, as "A condition affecting one, several or many bones, the graver cases of which may present abnormal pigmentation of the skin, premature sexual development, hyperthyroidism or still other extraskeletal abnormalities." The term, Albright's syndrome, has been applied to those cases in which disseminated bone lesions are associated with cutaneous pigmentation and sexual precocity in females.

Judging from the literature and from our own experience, it is evident that involvement of the skull is frequently observed in this condition and may, in fact, constitute its only manifestation. It is with this aspect of the disease and its neurosurgical implications that we are primarily concerned. Detailed accounts of a more general nature are available in a number of publications.[2,3,8,10,16,17,21,23,26,31,32,46]

*Pathology.* Involvement of osseous structures may occur alone or in association with the endocrine and cutaneous manifestations of Albright's syndrome. The skeletal lesions may be confined to a single bone (monostotic), or may involve a number of bones (polyostotic). Regardless of the clinical form assumed by the disease, the basic histopathologic changes are fundamentally identical in all cases. Within an affected bone, either flat or tubular, there takes place an accumulation of fibrous connective tissue. This may be cellular, consisting of spindle cells arranged in whorls, or densely collagenous. Dispersed throughout the connective tissue, trabeculae of immature bone may be frequently observed. This new bone is poorly formed, imperfectly calcified and may show evidence of osteoclastic resorption. In some cases the amount of bone laid down may be considerable, so that the connective-tissue element appears relatively insignificant. Islands of cartilage may also be observed within the fibrous tissue and occasionally small cysts, areas of hemorrhage, giant cells or foam cells are to be found. With the ter-

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mination of the active phase of the disease, the fibrodysplastic tissue may become increasingly ossified. In some bones, especially those of the skull, sclerotization of the fibrodysplastic tissue may eventually become extremely marked. As will be indicated later, the roentgenologic manifestations of this disorder are variable, depending on the relative amounts and distribution of fibrous tissue and bone.

Grossly such dysplastic tissue appears yellow or greyish-white, is of variable consistency, though usually firm and rubbery, and often feels gritty owing to the presence of many small bone spicules. It may occasionally contain small cysts filled with brown fluid. The skeletal structures affected by this disease may either retain their shape or become widened and deformed, or even fractured as a result of the expansile nature of the pathologic process.

*Etiology.* The etiology of this disorder is unknown. As indicated by Albright and his associates,[2] the regional distribution of the lesions would tend to exclude a metabolic or endocrine cause. They suggest that the responsible factor may be either a neurologic disturbance or an embryologic defect. A congenital anomaly of development that may account for both skeletal and extraskeletal features is advocated by Lichtenstein and Jaffe.[31,32] In keeping with this hypothesis, abnormal activity of the specific bone-forming mesenchyme would be the cause of the osseous lesions. The embryonic defect theory is also favored by Neller.[36] The possibility that the monostotic form of fibrous dysplasia may represent a disturbance of the normal reparative processes following injury is proposed by Schlumberger.[45] Derangement of liver function,[5] hormonal disturbances,[6,49] hyperemia caused by anomalies of the sympathetic nervous system,[19] and chronic hyperparathyroidism due to a hyperphosphatemia[24] have also been suggested as etiologic factors.

Snapper formerly was of the opinion that fibrous dysplasia represented a variant of Hand-Schüller-Christian's disease. In the latest edition of his book,[46] however, he has modified this view and concedes that in most cases this interpretation does not appear to have been substantiated. Thannhauser's[51] thesis that fibrous dysplasia is a form of neurofibromatosis of von Recklinghausen has been critically analyzed by Jaffe[25] and Albright.[1] Both reject this concept. The clinical and anatomic evidence they submit leaves little doubt that the two conditions are indeed separate entities.

*Clinical Aspects.* Fibrous dysplasia is primarily a disease of childhood, its progress frequently becoming retarded or arrested when adult life is reached and skeletal growth ceases. It is believed that in cases in which the disorder is first encountered later in life, the skeletal lesions originated during childhood. Females are more commonly affected than males. The usual clinical manifestations are limp, deformity, pain and pathologic fracture. In cases with advanced skull lesions, the degree of disfigurement may be considerable. This will be discussed in greater detail subsequently. When more than one bone is affected, the involvement is frequently exclusively or predominantly unilateral. It may be monomelic. Long bones are mainly affected, the proximal parts more than the distal. Thus the upper half of the

femur is often involved, resulting usually in an outward bowing referred to as the "shepherd crook" deformity. Other bones that may be implicated include the scapula, pelvis, clavicle, vertebrae, tarsal and carpal bones, ribs, sternum and mandible. In the series of 90 cases collected by Lichtenstein and Jaffe,[32] the extent of the lesion was known in 87, in 15 of which it was limited to a single bone. Probably the incidence of monostotic involvement is considerably greater. In 67 of the 69 cases Schlumberger[45] collected from the Army Institute of Pathology, the lesion was restricted to one bone. Additional instances have been recorded by Elmslie,[14] Freund and Meffert,[20] Wyatt and Randall,[56] and Wells.[53] To illustrate further the probable relative frequency of single lesions, in the recent publications of Proffitt, McSwain and Kalmon,[41] and Russell and Chandler,[44] the monostotic cases outnumbered the polyostotic.

Of the extraskeletal manifestations that are known to occur in fibrous dysplasia, the commonest, according to Jaffe,[26] is cutaneous pigmentation. The affected area of skin is yellow or yellow-brown in color, flat and of variable size. Albright[1] states that the pigmentation in cases of fibrous dysplasia is characterized by an irregular border reminiscent of the "coast of Maine," in contrast to that observed in neurofibromatosis, which possesses a more regular contour likened to the "coast of California." Its location may or may not correspond to that of the fibrodysplastic skeletal lesions. Though apparently uncommon, the occurrence of cutaneous pigmentation in monostotic cases has been reported by Jaffe,[26] Proffitt, McSwain and Kalmon[41] and by Russell and Chandler.[44]

Sexual precocity is found in a small proportion of cases, and in these, the osseous lesions as a rule are marked and widespread. Though most often observed in females, precocious sexual development has occasionally been reported in males.[17,30,52]

Accelerated skeletal growth and premature fusion of the epiphyses may occur. In such cases the children may at first appear unusually tall, but their final height is short due to early epiphyseal fusion. As indicated by Jaffe,[26] skeletal precocity has been observed mainly in patients exhibiting the several features of Albright's syndrome. Whether it occurs in cases in which the bony involvement is more limited, is uncertain.

Other extraskeletal manifestations reported in the literature include hyperthyroidism,[4,34,50] congenital arteriovenous aneurysms,[48] gynecomastia and other feminine characteristics in a male adolescent,[35] acromegalic features,[17] and coarctation of the aorta together with a rudimentary kidney.[7] A case of diabetes mellitus associated with Albright's syndrome was encountered by Peck and Sage.[39] In one of our patients with fibrodysplastic changes limited to the skull, an impaired carbohydrate tolerance was demonstrable.

Blood chemical studies are usually normal, though elevation of the alkaline phosphatase level has been reported.

The disease runs a protracted, slowly progressive course. Apparently a

relatively stabilized condition may be reached when the period of active skeletal growth comes to an end. Increasing deformity of an involved bone may, however, occur during adult life as a result of structural weakness. Occasionally, as observed by Jaffe,[26] a lesion that appears to have become quiescent may show signs of activity again after a lapse of many years. Four cases are on record in which sarcomas developed in an affected bone.[8,9,26]

*Roentgen Appearance.* When fibrous dysplasia affects a tubular bone, the changes observed on roentgenographic study involve the shaft and metaphyses, rarely the epiphyses. The basic lesion being a replacement of medullary bone by fibrous tissue, areas of decreased density may be seen. Since the involved bone is often expanded, and its cortex thinned, the roentgenographic picture takes on a cystic appearance. There may be ridges on the inner surface of the cortex of the bone giving the impression of a multilocular lesion. The presence of bony trabeculae in many of the apparently cystic areas gives rise to increased densities resembling ground glass or "columns of slowly ascending smoke."[34]

## FIBROUS DYSPLASIA OF THE SKULL

Cranial lesions are of frequent occurrence in polyostotic fibrous dysplasia. According to Windholz,[54] about half the cases with moderate skeletal involvement show skull changes; in those with marked skeletal manifestations, the skull is invariably affected. Involvement of the skull, on the other hand, occurs fairly frequently in the absence of demonstrable dysplastic lesions elsewhere in the body. Windholz is of the opinion that the cranium is affected in approximately 1 out of every 10 cases of the monostotic variety. Pugh[42] gathered 10 cases in which the disease apparently was limited to the cranium and facial bones, though in only 3 was a complete skeletal examination performed. The calvarium was the site of the lesion in 5 of the 67 monostotic cases reported by Schlumberger.[45] The frontal bone was involved in 2 instances while the parietal, temporal and occipital bones were each affected in 1 case. Localized osteitis fibrosa cystica of the frontoparietal skull in a child, undoubtedly an example of fibrous dysplasia, was recently described by Paget, Fricker and Ver Brugghen.[38]

It has been suggested by a number of observers that many of the cases classified as leontiasis ossea are in reality manifestations of fibrous dysplasia. The view that the two conditions might be closely related was proposed by Falconer, Cope and Robb-Smith[17] and is concurred in by Furst and Shapiro,[21] Dockerty and his associates,[10] Windholz and Cutting,[55] and by Fairbank.[16] Leontiasis ossea has generally been regarded not as a specific pathologic entity, but rather as a syndrome, of uncertain, though presumably diverse etiology. Paget's disease, osteitis fibrosa cystica of von Recklinghausen and inflammatory disease (Virchow's type) have been held responsible. The subject is well reviewed by Windholz and Cutting,[55] who conclude that the majority of cases described as Virchow's and von Recklinghausen's type of leontiasis ossea, in which there were no chemical alterations or dif-

fuse osteoporosis, were in all probability instances of fibrous dysplasia. Reference is also made to the work of Knaggs,[29] who divided the cases of leontiasis ossea into two groups—creeping periostitis and diffuse osteitis. The periostitic form was thought to result from bacterial infection and to originate in the nasal fossae or accessory sinuses. Spread of the infection was believed to take place on the undersurface of the periosteum and to be accompanied by an osteitis of the adjacent bone, resulting in subperiosteal bone deposition. The cases of diffuse osteitis, regarded by Knaggs as synonymous with osteitis fibrosa, were further divided into a general diffuse osteitis of the cranial and facial bones, a circumscribed form, and an osteitis beginning in one or both jaws and rarely spreading far beyond them. Histologically, this form of leontiasis ossea is characterized by an accumulation of vascular and cellular connective tissue in which new bone develops through metaplasia of the fibrous tissue. Windholz and Cutting are of the opinion that many of the cases classified by Knaggs as diffuse osteitis were probably instances of Paget's disease or fibrous dysplasia. Fairbank,[16] who also reviewed Knaggs' work, goes even further and states that he is not convinced that there is any material difference in the two groups, nor that any of the cases appear to belong in the category of Paget's disease. He believes that "there seems no reason for regarding leontiasis ossea occurring alone as different and distinct from the hyperostoses of the skull seen in many cases of polyostotic fibrous dysplasia."

The lesion designated as an ossifying fibroma or fibrous osteoma also appears to be closely related to fibrous dysplasia. This view, originally propounded by Lichtenstein,[31] is also held by Schlumberger[45] and by Jaffe.[27] Jaffe is inclined to regard an ossifying fibroma or fibrous osteoma as a very osseous form of fibro-osseous dysplasia. Such lesions have been observed in the jaw and other bones of the skull. Eden[13] described a group of benign fibro-osseous tumors of the membrane bones of the vault of the skull and face which were unassociated with general skeletal disease, arose in one or more foci usually early in life and grew slowly for many years before becoming stationary. They possessed an essentially similar structure, arising as a result of a transformation of fibrous tissue into bone by metaplasia. To quote Eden, "they range from the ossifying fibromas of the jaws, which contain only small amounts of bone and were formerly regarded as pure fibromas, to the mature bony compact osteomas and include many varieties of intermediate hyperostoses, frequently described as focal osteitis fibrosa." These fibro-osseous tumors were divided into four groups: the ossifying fibromas, the fibrous or spongy osteomas limited to a part or whole of one bone, the localized compact osteomas, and the diffuse osteomas or hyperostoses involving several adjacent bones. The ossifying fibromas most commonly were observed in the horizontal ramus of the mandible and in the walls of the antra. A case in which a structurally similar process affected the frontal bone was also described. Histologically these lesions consisted of mature fibrous tissue in which there were scattered areas of calcification and ossi-

fication, and well developed blood vessels. They were interpreted to represent the most immature form of benign fibro-osseous tumor involving membranous bone. The localized osteomas were of two varieties, fibrous and compact. Though apt to occur anywhere in the membranous bones of the skull and face, these lesions most commonly arise in the frontal and facial regions. In Eden's series of 10 cases of localized fibrous osteomas, 5 were maxillary, 2 frontal, 2 mandibular and 1 temporo-occipital. Microscopically these tumors displayed trabeculae of newly formed primitive bone irregularly dispersed in a fibrous stroma of varying cellularity. The compact or ivory osteomas were found to involve any of the membrane bones of the skull and face, arising on either table of the mandible along the alveolar margin, on the hard palate and surface of the zygoma and maxilla, on either side of the bones of the vault of the skull, often in the external auditory meatus and orbit, and in the antra and frontal sinuses. They were composed of mature, dense, laminated bone with small haversian systems. Eden regarded this type as "the most mature and localized form of the fibro-osseous tumors of the membrane bones. It is periosteal and subperiosteal in origin, and although fibrous tissue may be almost absent, the tumor is formed in a manner similar to the more fibrous types, and all stages of transition are found between the two groups." The diffuse osteomas, comprising Eden's last type, differed from the localized fibrous osteomas only in that the disease was not limited to a single bone. Such cases have been described under the name of leontiasis ossea, and are synonymous with the second group of Knaggs, referred to previously. The microscopic structure of the bone in these cases was identical with that of the more localized fibrous osteomas, being characterized by a diffuse replacement of the marrow by fibrous tissue in which new bone was deposited. As stated by Eden, "the trabeculae pass in all directions, and may be slender, composed mostly of woven bone and separated widely by fibrous tissue in the more spongy types; and stouter, formed of laminated bone and separated only by narrow tracts of fibrous tissue, in the denser types. Osteoclastic resorption of bone and re-formation of bone by osteoblasts may be active, or the process may appear quiescent with evidence of extensive old remodelling."

A series of cranial osteomas comparable to the localized osteomas of Eden was reported by Echlin.[12] These involved the external surface of the cranium, most often the frontal bone. Spongy and eburnated, as well as intermediary forms, were encountered. It was stressed by the author that these several types represented different stages of the same process, all apparently arising from the deeper layers of the periosteum. The eburnated tumors were composed of quiescent adult cortical and cancellous bone, the spongy tumors of proliferating preosseous tissue, derived from spindle-shaped fibroblasts, and trabeculae of young bone. Most of the osteomas, especially those of the spongy variety, arose at an early age.

*Roentgen Appearance.* The roentgenographic changes observed in the skull in cases of fibrous dysplasia are not uniform. The cyst-like, translucent

areas typically found elsewhere in the skeleton are less often encountered in the skull. They are usually restricted to the calvarium and are associated with widening of the diploe and thinning of the tables. According to Windholz[54] such translucencies possess a dense margin and may or may not extend beyond the surface of the outer table. In none of his cases did the cysts extend through sutures. Such lesions have been observed in the occipital, frontal and parietal bones. More commonly the skull is the site of extensive new bone formation which causes an increase in the thickness and density of the affected structures. While bone deposition of a pronounced degree is especially evident in cases in which the base of the skull is involved, the vault may be similarly affected. The localization of the skull and facial lesions may be unilateral and restricted to the side of the skeletal lesions when the latter involve only one side of the body. In the more severe cases, the skull changes are extensive. The calvarium, roofs of the orbits, the wings of the sphenoid bones, the anterior and posterior clinoids, the malar bones, paranasal sinuses and mandible may all be affected. At times, as in some of the cases to be described, the extent of the lesion may be sharply circumscribed.

According to Dyke,[11] in cases of leontiasis ossea, localized or generalized, thickening of the bones of the skull may be observed. In the localized form, the frontal bone and superior maxillae are affected, resulting in encroachment on the orbital cavities and obliteration of the antra. The vault and base, especially the former, are thickened in the generalized form. Both types may be associated with sclerosis of other skeletal parts.

The localized fibrous osteomas (Eden) are characterized radiographically by a shell of cortical bone continuous with the adjacent outer table surrounding a mass of fine, spongy new bone extending into the diploe. Expansion of the bone may be observed. The inner table may be unaffected or thickened and extend into the cranial cavity.

In cases of what has been referred to as osteitis fibrosa localisata affecting the bones of the face and skull, there usually is also found expansion of the cavity of long bones, which become less dense than normal (Dyke[11]).

## AUTHORS' EXPERIENCE

Our experience with fibrous dysplasia consists of 5 cases, 2 definitely of the monostotic variety and 3 presumably so. Symptoms referable to the eye led to neurosurgical consultation in 3 instances. The lesion was accidentally disclosed in 1 patient when x-rays were taken following an injury. An operation was performed in 4 cases, in 3 of which the preoperative diagnosis was a meningioma; 1 was diagnosed an osteoma. In the remaining patient the diagnosis was established on clinical grounds and subsequently verified histologically. Unilateral exophthalmos was observed in 3 of the patients subjected to operation, and optic atrophy in 1. The symptoms of the patient not operated upon were deformity of the skull and unilateral impairment of hearing. At the time they were observed in this clinic, 2 of the

patients were in the first decade of life, 1 in the second, and 2 in the third. The roentgenographic appearance in 3 cases was that of a sharply localized calcific mass in the anterior fossa.

## CASE HISTORIES

Case 1. *R.R. J.H. #279632. Unilateral exophthalmos in a 13-year-old girl caused by fibrous dysplasia involving the orbital roof. Craniotomy with removal of lesion. Recurrence within a year. No further symptoms 5 years following reoperation.*

*History.* A 13-year-old girl was admitted on Nov. 29, 1944 because of unilateral exophthalmos of 4 months' duration. This involved the left eye and was progressive in character. It was not associated with any disturbance of vision or with other symptoms referable to the nervous system. Menstruation had not yet begun.

*Examination.* There was a distinct proptosis of the left eye. Exophthalmometer measurements were 17 on the right and 21.5 on the left. Visual fields were normal. The retinal veins, especially those on the left, appeared congested. A slight lid lag involving the left eye was also noted. There was no abnormal cutaneous pigmentation.

*Laboratory Data.* Blood and urine were normal. Blood serology was negative. B.M.R. was −5.5. Roentgenograms of the skull revealed a calcific lesion involving the left orbital plate and sphenoid wing. It extended downward into the orbit and upward into the anterior fossa. The sella turcica appeared normal and there was no evidence of increased intracranial pressure. Diagnosis: Psammomatous meningioma.

*Operation.* On Dec. 4, 1944, under avertin endotracheal anesthesia, a left transfrontal craniotomy was performed. The dura was opened and the frontal lobe retracted in search of an intradural lesion. None was found. It was possible, however, to visualize a purplish-brown extradural mass overlying the orbital plate. The dura was therefore peeled off the floor of the anterior fossa, permitting direct access to the lesion, which involved the middle of the posterior half of the orbital roof. It had

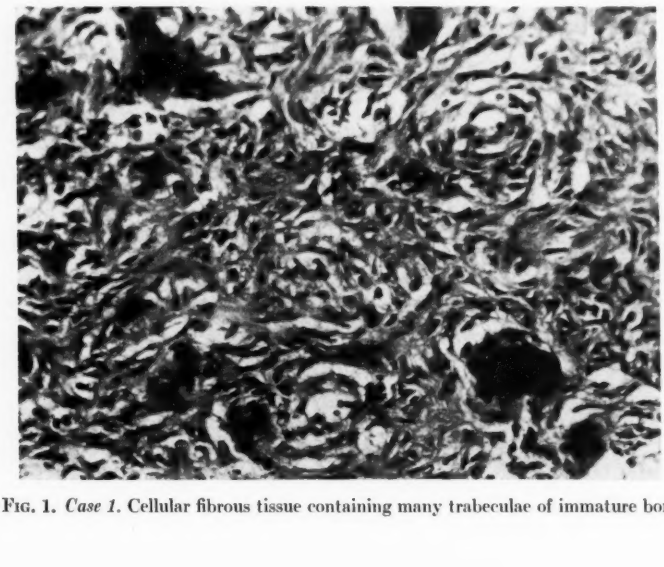

FIG. 1. *Case 1.* Cellular fibrous tissue containing many trabeculae of immature bone.

expanded the orbital plate and attenuated its walls so that it was contained within a bony shell. This was readily punctured with a blunt instrument. A needle was inserted and a small quantity of dark brown fluid removed. What appeared to be a complete excision of the mass and its capsule was then performed. The tissue removed was moderately firm in consistency and imparted a gritty sensation when sectioned.

*Histology.* The specimen consisted basically of fibrous connective tissue. It was composed chiefly of spindle-shaped cells with fusiform, vesicular nuclei containing small or inconspicuous nucleoli. There was a pronounced tendency for the cells to arrange themselves in small whorls. No mitotic figures were seen. For the most part the spindle cells were separated by only a small amount of fibrillar intercellular material, but in some areas the cells were so closely packed that there appeared to be no intercellular fibers whatever. Scattered throughout the fibrous tissue were numerous, small, newly formed, irregular trabeculae of "coarse fiber bone." About some of these there was a rim of osteoblasts and osteoid tissue. A few contained foci of calcification. Also present in the fibrous tissue were vascular channels and a few multinucleated giant cells (Fig. 1).

FIG. 2. *Case 1.* Calcific mass (arrow) involving left orbital plate and sphenoid wing. The original roentgenogram taken prior to the first operation showed a similar but less clearly defined lesion.

*Course.* The postoperative course was in no way unusual and, at the time of discharge on Dec. 16, 1944, the degree of exophthalmos had diminished considerably. The patient continued to improve until October, 1945 when the left eye began to bulge again. A recurrence of the lesion was suspected and this impression was confirmed by roentgen examination. The medial portion of the sphenoid ridge on the left, including the region of the optic foramen, appeared deformed and displaced downward. In the lateral projection a well defined bony elevation was visualized in front of the anterior clinoid involving the superior orbital wall (Fig. 2). Reoperation was performed on Dec. 11, 1945. The lesion again was located entirely extradurally. The defect left in the orbital roof at the previous operation had become obliterated as a result of new bone formation. Within the orbital plate a mass containing both bony and soft tissue elements was exposed. A gross total removal was accomplished. The orbital fascia was opened, providing for a decompression of the orbital contents. The patient did well and at the time of discharge on the 11th postoperative day, the proptosis had completely receded. The histological appearance of the specimen was identical with that of the tissue removed at the first operation. The patient has remained under observation for 5 years and has shown no further evidence of recurrence.

Case 2. *R.L. J.H. #246598. Unilateral exophthalmos in a 9-year-old boy resulting from fibrous dysplasia affecting the orbital roof. Disappearance of exophthalmos following surgical treatment.*

FIG. 3. *Case 2.* A dense homogeneous mass (arrow) is present over the right orbital plate. Note similarity to Case 1.

*History.* A 9-year-old boy was admitted on Sept. 5, 1941 because of increasing prominence of the right eye for 9 months. There were no other symptoms.

*Examination.* Exophthalmos of the right eye was the only positive neurological finding.

*Laboratory Data.* Blood and urine were normal. Blood and CSF serology were negative. CSF protein was 23 mg. per cent. Roentgenograms of the skull disclosed a dense homogeneous mass, 3.5 cm. long and 2 cm. thick, involving the right orbital plate (Fig. 3). No vascular channels were observed leading towards this lesion. A pneumoencephalogram showed no encroachment on the ventricles or basilar cisterns. It was thought that the lesion probably was an osteoma.

*Operation.* A right transfrontal craniotomy was done under avertin endotracheal anesthesia on Sept. 18, 1941. The dura was retracted from the orbital plate, exposing what at first appeared to be a bony tumor. As soon as the lesion was entered, however, it became evident that it was actually a soft tissue mass infiltrated with calcific deposits. The operator described the feeling it imparted to a sharp curette as similar to that experienced when scraping a piece of ice. The tissue was of uniform consistency, and devoid of large blood vessels. A gross total removal of the lesion was accomplished.

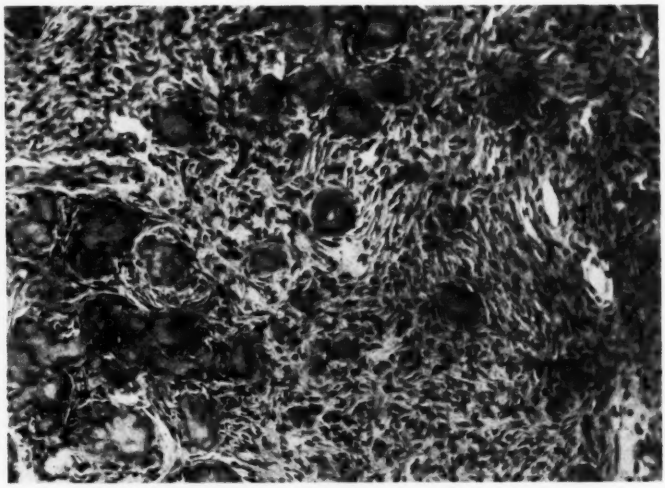

FIG. 4. *Case 2.* Numerous trabeculae of newly formed bone are scattered throughout the fibrous tissue. Care must be taken not to confuse this picture with whorl formation commonly seen in meningiomas

*Histology.* The lesion was composed of fibrous tissue containing newly formed bone. The fibrous tissue varied in its degree of cellularity, though most of it was rich in spindle-shaped cells. Prominently scattered throughout the fibrous tissue were newly formed trabeculae of primitive bone. These showed no characteristic arrangement, and were represented by irregular islands of pale eosinophilic and somewhat basophilic staining "coarse fiber bone." Foci of calcification were noted in some. In places the trabeculae were surrounded by osteoblasts and osteoid tissue. These immature trabeculae contained very few normal-appearing osteocytes. Multinucleated giant cells and areas of hemorrhage were noted occasionally (Fig. 4).

*Course.* At the time of discharge, 12 days after operation, exophthalmos was no longer evident. During the next 4 years, he remained asymptomatic. No further followup is available.

FIGS. 5 and 6. *Case 3.* Thickening of roof of left orbit and of sphenoid ridge (arrow). Roentgenographic picture suggests a hyperostosing sphenoid ridge meningioma.

Case 3. *J.A. B.I.H. #221772. Fibrous dysplasia involving orbit in a 9-year-old boy. Slight displacement of eyeball downward and forward. Craniectomy with subsequent repair of defect.*

*History.* A 9-year-old boy came under observation on Aug. 29, 1949. On July 1, 1949 he had been struck over the left eye with a baseball. The area became swollen and he was placed under the care of a physician. Roentgenograms of the skull showed changes in the region of the left orbit, and because of these further investigation was advised. The child's parents denied the presence of a deformity about the eye prior to the accident. Within a few days following the injury, the periorbital swelling subsided. At no time had he experienced headache, visual impairment, diplopia, or other neurologic symptoms.

His past history was not remarkable except possibly for the fact that he had been delivered by forceps and a mark over the left eye, caused by the instrument, had been present for the first few days after birth.

*Examination.* There was a prominence of the supraorbital ridge and temporal side of the orbit on the left side. A hard mass was palpable in this region. The left eye appeared displaced slightly forward and downward. Ocular motility was grossly

unimpaired. Neither papilledema nor optic atrophy was evident. The retinal veins were full, especially those of the left eye. Visual acuity was 20/25, corrected, bilaterally. Exophthalmometer readings were 11 on the right and 12 to 13 on the left. The pupils were equal in size, and reacted promptly to light and accommodation. The peripheral fields of vision were normal. No pigmented areas were observed.

*Laboratory Data.* Blood and urine were normal. EEG disclosed a diminished alpha amplitude in the left temporal region. Roentgenograms of the skull revealed an eburnation and thickening of the roof of the left orbit as far back as the tuberculum sellae, the lesser wing of the sphenoid, and the reflection of the greater wing of the sphenoid on the lateral cranial vault. The edges of the thickened bone were smooth and the increase in density homogeneous (Figs. 5 and 6). These changes had resulted in a diminution in volume of the left orbit. Undoubtedly the skull changes long antedated the injury. Diagnosis: Sphenoid wing meningioma.

*Operation.* On Aug. 31, 1949 a local craniectomy was performed under endotracheal anesthesia. A semilunar incision was made in the left frontal region and the scalp reflected so as to gain access to the base of the anterior fossa. The entire orbital ridge on the left side and the most mesial portion of the ridge on the right side were involved by the lesion. The presenting abnormal tissue was removed piecemeal and the orbital plate exposed. This too was abnormal, as far back as the margin of the lesser wing of the sphenoid. The superior and lateral walls and the upper part of the medial wall of the orbit were removed in an attempt to eradicate the lesion, but probably a small amount was left behind close to the bridge of the nose. There was no evidence that the intradural contents were implicated by the pathologic process. The ethmoidal sinuses, which had been laid open on both sides, were covered both by gelfoam soaked in penicillin and a transplant of pericranium, after which the wound was closed.

*Histology.* The lesion was an admixture of fibrous tissue and trabeculae of bone.

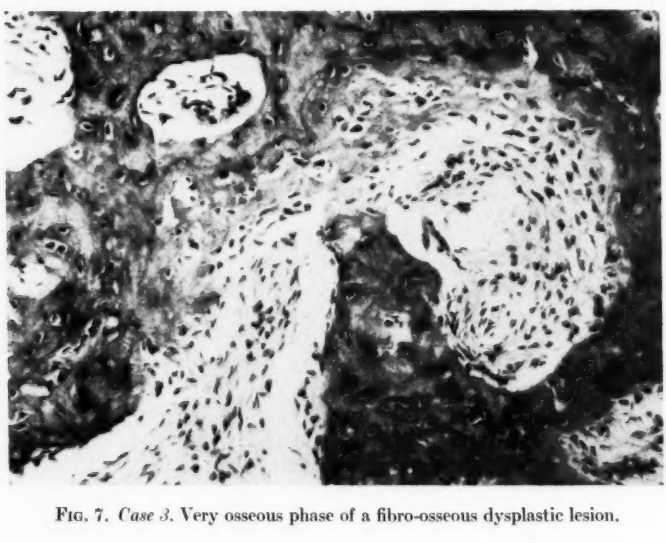

FIG. 7. *Case 3.* Very osseous phase of a fibro-osseous dysplastic lesion.

Evidence of bone resorption was noted in the form of Howship's lacunae filled with osteoclasts. In places there was osteoid tissue formation. The fibrous tissue was fairly cellular, its compactness varying. For the most part the fibroblasts were spindle-shaped with ovoid nuclei. Some had hyperchromatic pyknotic nuclei. No mitotic figures were noted. Throughout the fibrous tissue small vascular channels were prominent. Very few giant cells and lipoid-laden macrophages were seen. The portion of cortical bone present showed a normal lamellar arrangement. The microscopic appearance of the tissue was that of a very osseous phase of a fibro-osseous dysplastic lesion (Fig. 7).

*Course.* Postoperatively the child noticed diplopia in all fields of gaze. A skeletal survey was done which failed to demonstrate involvement of other bones. He was readmitted on April 24, 1950 and the skull defect was repaired, utilizing a preformed stainless steel plate. The diplopia at this time had largely disappeared and the eyeball appeared to have receded.

Case 4. *D.W. M.H. #45557. Unilateral optic atrophy in a 25-year-old female caused by fibrous dysplasia involving the region of the tuberculum sellae. Decompression of optic nerves and chiasm. Postoperative fatality.*

*History.* A 25-year-old female was admitted Sept. 30, 1948 because of impairment of vision of the left eye. About a year prior to admission, during a routine physical examination, evidence of pressure on the left optic nerve had been found; skull films demonstrated a lesion involving the tuberculum sellae. She became aware of diminished visual acuity only about 6 months before admission. During this time visual failure had not been progressive. She presented no other symptoms. Her menses had begun at the age of 12 years and were normal. Her past history was negative.

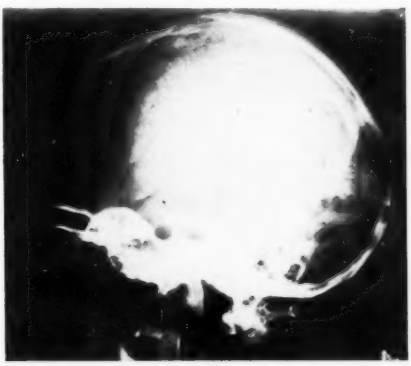

FIG. 8. *Case 4.* Bony mass in region of tuberculum sellae. The surface of the lesion is distinctly denser.

*Examination.* The only significant findings involved the left eye. The left pupil was slightly larger than the right and reacted sluggishly to light. Funduscopic examination revealed a sharply outlined white optic nerve head, indicative of primary atrophy. Visual acuity on the right was normal; on the left it was reduced to finger counting at a distance of 1 ft. in the nasal field. Central and peripheral fields on the right were normal.

*Laboratory Data.* Blood count, urinalysis and blood chemical studies disclosed no abnormalities. EEG showed a normal pattern. Roentgenograms of the skull demonstrated a bony mass in the posterior medial part of the floor of both anterior fossae. This lesion was not uniformly opaque, its surface being distinctly denser than its inner portion (Fig. 8).

*Operation.* The nature of this mass was not altogether clear. On the assumption that it might represent a calcified meningioma, a right transfrontal craniotomy was performed under endotracheal anesthesia on Oct. 1, 1948. When the frontal lobe was retracted away from the floor of the anterior fossa, an extradural tumor arising

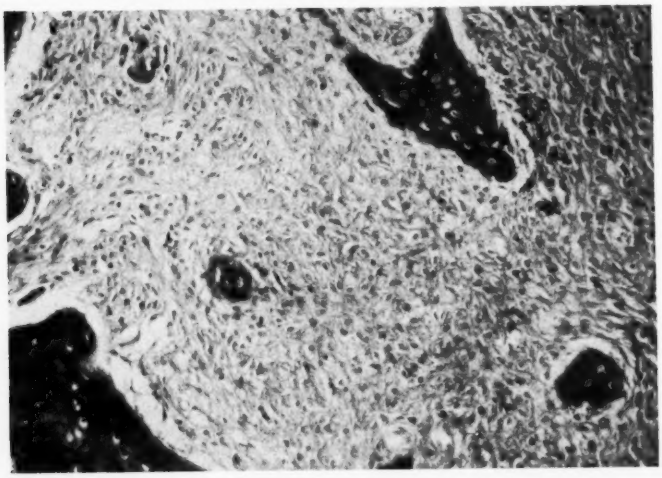

FIG. 9. *Case 4.* Newly formed bone is present in a matrix of fibrous tissue.

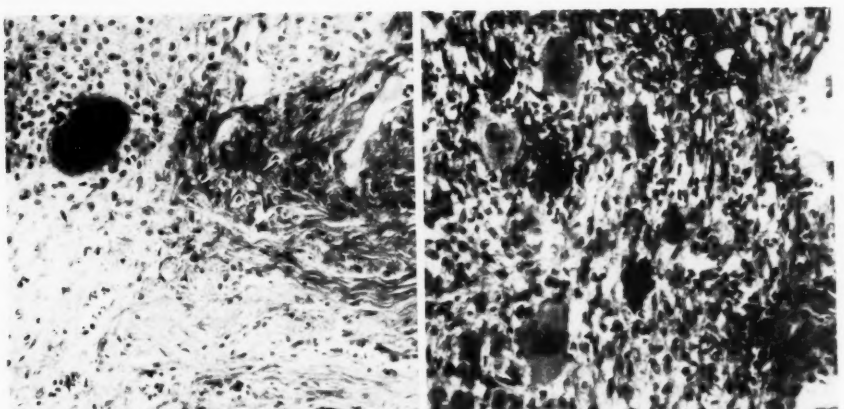

FIG. 10 (*left*). *Case 4.* Section showing immature bone, cartilaginous and fibrous tissue.
FIG. 11 (*right*). *Case 4.* Area of hemorrhage showing presence of giant cells.

from the orbital plate in the region of the olfactory groove and extending back to the anterior clinoid processes was exposed. It possessed a hard shell and contained gritty material suggesting psammomatous tissue. To the surgeon it appeared more than likely that the lesion was a calcified meningioma. A subtotal removal was accomplished, sufficient in amount to decompress the optic nerves and chiasm. The left optic nerve was found to be about half the size of the right one and grayish in color. Although the operation presented no great difficulties, the patient expired 48 hours later.

*Histology.* Microscopic examination of the tissue revealed the presence of fibroblastic cells arranged for the most part in parallel rows, though occasionally there was a suggestion of whorl formation. Scattered among these cells were numerous areas of new bone formation in various stages of development, as well as islands of cartilage. Osteoblasts were present around many of the new bone fragments. Giant cells were noted where extravasation of blood had taken place (Figs. 9, 10 and 11).

Case 5. *A.J. Deformity of skull in a 28-year-old male, resulting from extensive fibrous dysplasia of cranium and face. Duration 21 years. Disease clinically inactive.*

*History.* A 28-year-old man was referred for an opinion in August 1949 as to the nature of a mass in the right temporal region. A lump had been present in this area since the age of 7 years. It had slowly become more prominent until 5 or 6 years before admission, when it had ceased to enlarge. A gradual diminution in hearing had taken place on the involved side, beginning at the age of 14 or 15 years. The patient was reasonably sure that no further loss of hearing had occurred in recent years. He had on occasion experienced pain during the winter months over the entire right side of the face, but this symptom had not recurred in the past 7 years. No other complaints were elicited.

FIG. 12. *Case 5.* Extreme degree of bony overgrowth involving vault and base of skull, and bones of face on right side.

His past history was in no way unusual. The family history was noteworthy in that his father had died of a hypernephroma and his mother was a schizophrenic.

*Examination.* The most conspicuous finding was a hard, non-tender mass involving the right temporal region and zygoma. Hearing was grossly defective on the right side, bone conduction being prolonged over air, and a tuning fork placed over the forehead was lateralized to that side. It was the opinion of the otorhinolaryngologist that an air conduction deafness existed, caused by an obstruction of the external canal. There was no evidence of defective trigeminal function.

*Laboratory Data.* Blood and urine were normal. Blood serology was negative. Sedimentation rate was slightly elevated, measuring 23 mm./hr. Blood chemical

findings were cholesterol 184 mg. per cent; cholesterol esters 115 mg. per cent; total serum protein 7.25 gm./100 cc.; albumin 4.1 gm.; globulin 3.1 gm.; calcium 9.0 mg. per cent; phosphorus 4.0 mg. per cent; serum alkaline phosphatase 4.8 units (Bodansky u.); NPN 41.5 mg. per cent; uric acid 4.1 mg. per cent; glucose 123 mg. per cent. A glucose tolerance test revealed subclinical diabetes mellitus; the blood sugar level rose to 242 mg. per cent at the end of 16 min. and failed to return to normal after 2 hr. B.M.R. was +3.

The entire skeleton was x-rayed but changes were observed only in the skull. These consisted of an intense hyperostosis involving the vault, zygoma, maxilla, petrous ridge, mastoid and supraorbital region on the right side. The frontotemporal region of the calvarium was thickened, its maximum width measuring 3.5 cm. An oval-shaped area of decreased density was visible within the hyperostosis near the surface of the bone in the anteroposterior projection (Fig. 12). Clinical impression: Fibrous dysplasia.

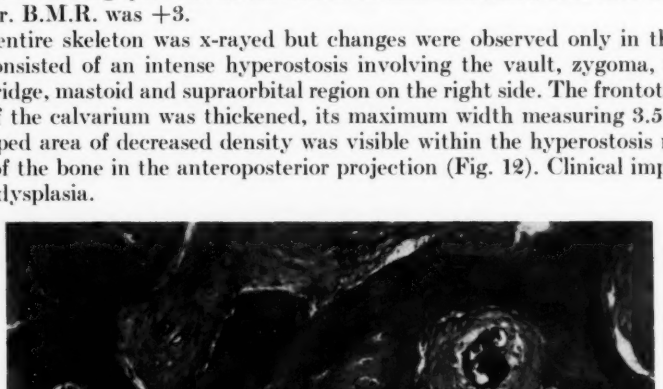

FIG. 13. *Case 5.* Biopsy specimen, showing fibro-osseous character of tissue.

*Histology.* A biopsy was taken from the involved temporal bone. Sections showed fibrous tissue with large amounts of osseous tissue forming a typical pattern of fibrous dysplasia. About the bony trabeculae both osteoblastic and osteoclastic activity was noted. Howship's lacunae were in evidence, indicating active bone resorption. The cement lines of the trabeculae were fairly prominent, but the mosaic structure, characteristic of Paget's disease, was not observed. The fibrous tissue was compact, well vascularized and contained an abundance of spindle-shaped cells. Foci of lipoid-laden phagocytes were present. An occasional small spicule of primitive "coarse fiber bone" was seen (Fig. 13).

## COMMENT

In a discussion of the paper by Pugh, Sosman[47] stated that the one condition with which fibrous dysplasia of the cranium is most apt to be confused is a meningioma. He further added that at the time the original publication of Albright and his associates appeared, he had already collected 9 such cases

referred to Cushing as possible meningiomas. That the two conditions may offer a real problem in differential diagnosis is borne out by our experience. This is particularly true of lesions that are relatively localized and involve the base of the skull. In our series the floor of the anterior fossa was frequently the site of the disease, leading to the suspicion of a meningioma in this region in 3 instances. The orbital plate, sphenoid ridge and tuberculum sellae were each thought to harbor such a growth. While the likelihood of a fibrodysplastic lesion may be suspected, it may not be possible to exclude a meningioma by any means short of operation. A most important differentiating clue is the age of the patient. Fibrous dysplasia usually manifests itself in a young person, often during childhood. Meningiomas, on the other hand, occur later in life. One wonders whether the case described recently by MacCarty and Gogela[33] as a sphenoid ridge meningioma in a 12-year-old child was not actually one of fibrous dysplasia.

Cases in which there is extensive cranial involvement will ordinarily offer no problem in diagnosis. The associated deformity and dense bony deposits will readily identify the nature of the pathologic process. Nor should the differentiation between fibrous dysplasia and the hyperostosis associated with a meningioma be difficult when the vault is the site of the lesion. The bony reaction of a meningioma is circumscribed, and in contrast to fibrous dysplasia, which begins in the diploe, first affects the inner table, resulting in an enostosis. Localized increase in vascularity, characteristic of a meningioma but absent in fibrous dysplasia, is another distinguishing feature. The fact that meningiomas tend to originate at certain favorite sites and are associated with characteristic neurologic syndromes in specific locations may be of additional help. The examiner should keep in mind, moreover, the fact that extraskeletal manifestations, such as cutaneous pigmentation and sexual precocity, may accompany fibrous dysplasia. Furthermore, since the cranial manifestations may be part of a polyostotic process, in suspected cases the entire skeleton should be studied in search of other foci.

In addition to meningioma, there are several other entities which may cause confusion with fibrous dysplasia. Hyperparathyroidism should offer no problem in differential diagnosis since the appearance of the cranium is one of generalized demineralization, without hyperostoses. Moreover, the entire skeleton is involved in this condition, and blood chemical studies disclose characteristic alterations in the phosphorus and calcium levels. Paget's disease usually occurs later in life and presents a fairly characteristic roentgen picture. The bones of the vault become diffusely thickened due to widening of the diploe and outer table, and develop a "cotton-wool" or "coarse moth-eaten" appearance. It is unusual for the area involved to be circumscribed. The base of the skull is commonly affected also. Windholz and Cutting[55] observed changes in the facial bones only after the vault and base of the skull were already extensively involved. Lipoid granulomatosis should be readily distinguished by the presence of multiple defects of varying size occurring in the bones of the vault and base. Occasionally only a

solitary lesion is observed in this condition. Frequently similar changes may be demonstrated elsewhere in the skeletal system. Should diabetes insipidus and exophthalmos occur in conjunction with the skull defects, especially in a child, the diagnosis of Hand-Schüller-Christian disease is virtually assured. In doubtful cases a trial of radiation therapy should clarify the issue. Benign giant-cell tumors seldom involve the cranial bones. In the few reported cases the site of the tumor has usually been an intracartilaginous bone. According to Geschickter and Copeland,[22] such growths produce a sharply outlined area of bone destruction.

Reference to the osteomas and their possible relationship to fibrous dysplasia has already been made elsewhere in this paper. The compact osteomas arise most often from the outer table, frequently in the frontal region. Roentgen examination reveals a well defined, round, homogeneous, dense shadow. The basilar sphenoidal and ethmoidal osteochondromas occurring in young adults may be recognized by their characteristic radiographic appearance. This consists of a combination of bony erosion and dense or flaky calcification. Their parasellar location often results in a neurologic picture indicative of involvement of this region. Other conditions that conceivably might bear a superficial resemblance to fibrous dysplasia are hemangioma of bone, metastatic malignancy, cholesteatoma and inflammatory disease. Their radiographic appearance is ordinarily sufficiently distinctive to establish their identity. Undoubtedly, at times, a biopsy and histologic examination will be required to establish the correct diagnosis.

With regard to clinical symptomatology, fibrous dysplasia affecting the skull may produce varying degrees of deformity. This may be relatively mild, being evident only as an asymmetry of the face or head, or extremely pronounced. Obstruction of the paranasal sinuses and lacrimal ducts may give rise to symptoms. Ocular manifestations are frequently encountered. These include deformity of the orbit, exophthalmos and displacement of the eye. Proptosis was noted in 3 of our patients, in one of whom the eye was, in addition, displaced downward. Ocular involvement has been reported by other observers. The occurrence of exophthalmos is mentioned, for example, in the reports of Albright, Scoville and Sulkowitch,[4] Stauffer, Arbuckle and Aegerter,[48] Falconer, Cope and Robb-Smith[17] and Pugh.[42] Eden[13] states that the ossifying fibromas and fibrous osteomas may cause proptosis. Reference to osteitis fibrosa cystica as a cause of exophthalmos is also to be found in the ophthalmic literature (Pfeiffer,[40] Reese[43]). Ocular depression has been reported by Etter and Hurst,[15] by Sosman[47] and by Schlumberger.[45] Disturbance of extraocular motility was observed in the case of Stauffer and his associates. Visual impairment, manifested as optic atrophy in 1 of our patients, has been described by others too. Stauffer *et al.* observed early unilateral papilledema and a relative central scotoma in their case. A combination of papilledema in one eye and optic atrophy in the other, associated with a central scotoma on the side of the atrophy, was found in 1 of the 2 cases reported by Falconer, Cope and Robb-Smith. Examination of

their second patient disclosed bilateral optic atrophy and bitemporal hemianopic scotomas. Unilateral choked disc was found in 1 of the cases described by Furst and Shapiro.[21] Ford[18] mentions a case of osteitis fibrosa in a child, affecting the frontal bone and orbit, which was associated with exophthalmos and optic atrophy. Decompression of the orbit and optic foramen resulted in some improvement.

Hearing was affected and a history of facial pain elicited in 1 of our patients. Such symptoms are known to occur in leontiasis ossea which, as we have already indicated, is believed to be a manifestation of fibrous dysplasia in some cases at least. Kanavel[28] collected 34 cases of leontiasis ossea, in 11 of which there was a history of neuralgic pains and in 4 of which hearing was impaired. The occurrence of headache, convulsions and mental impairment is also recorded. Mention is made by Oppenheim[37] of a condition of "diffuse hyperostosis" occurring at an early age and characterized by an increase in the size of all cranial bones, in which a diminution in volume of the cranial fossae and orbits and narrowing of foramina may lead to blindness, deafness, exophthalmos, headache and dementia. Clearly the situation with regard to neurologic symptoms in fibrous dysplasia is analogous in many respects to that of Paget's disease.

There is no specific treatment for fibrous dysplasia. Just as long bone involvement may require orthopedic treatment for the purpose of dealing with fractures and deformities, neurosurgical intervention may be necessary in cranial cases in order to provide symptomatic relief. Surgical measures will probably be indicated chiefly for the treatment of progressive exophthalmos and compression of the optic nerves and chiasm. Possibly cosmetic considerations may at times justify surgical therapy.

## SUMMARY

The pathologic, clinical and radiographic aspects of fibrous dysplasia are reviewed, with special emphasis on cranial involvement. The probable relationship of this disease to leontiasis ossea and fibro-osseous tumors of the skull is discussed. Five cases of fibrous dysplasia of the skull observed by the authors are presented. Two were definitely of the monostotic variety and 3 presumably so.

Involvement of the skull is known to occur frequently in polyostotic fibrous dysplasia. At times, however, the skull appears to be exclusively affected by this disease. In cases with cranial involvement, particularly when the base of the skull is the site of the lesion, localized clinical symptoms may be present. Ocular manifestations are especially likely to be prominent.

Confusion may arise in distinguishing between localized fibrous dysplasia and the bony changes associated with a meningioma. One of the most valuable differential criteria is the age of the patient. Fibrous dysplasia is a disorder of childhood and adolescence. Meningiomas as a rule occur during adult life.

The etiology of fibrous dysplasia is unknown and there is no specific

treatment for it. Progressive exophthalmos and compression of cranial nerves may call for neurosurgical intervention.

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## REFERENCES

1. Albright, F. Polyostotic fibrous dysplasia: a defense of the entity. *J. clin. Endocrinol.*, 1947, *7:* 307–324.
2. Albright, F., Butler, A. M., Hampton, A. O., and Smith, P. Syndrome characterized by osteitis fibrosa disseminata, areas of pigmentation and endocrine dysfunction, with precocious puberty in females. *New Engl. J. Med.*, 1937, *216:* 727–746.
3. Albright, F., and Reifenstein, E. C., Jr. The parathyroid glands and metabolic bone disease. Selected studies. *Baltimore: Williams & Wilkins* Co., 1948, 393 pp.
4. Albright, F., Scoville, B., and Sulkowitch, H. W. Syndrome characterized by osteitis fibrosa disseminata, areas of pigmentation, and a gonadal dysfunction. *Endocrinology*, 1938, *22:* 411–421.
5. Braid, F. Osseous dystrophy following icterus gravis neonatorum: generalized osteitis fibrosa with areas of pigmentation of the skin and precocious puberty in the female. *Arch. Dis. Childh.*, 1939, *14:* 181–202.
6. Bremer, J. L. Osteitis fibrosa localisata. An experimental study. *Arch. Path.*, 1941, *32:* 200–210.
7. Coleman, M. Osteitis fibrosa disseminata. Report of a case. *Brit. J. Surg.*, 1939, *26:* 705–713.
8. Coley, B. L. Neoplasms of bone and related conditions. Their etiology, pathogenesis, diagnosis and treatment. *New York: P. B. Hoeber, Inc.*, 1949, xiv, 765 pp.
9. Coley, B. L., and Stewart, F. W. Bone sarcoma in polyostotic fibrous dysplasia. *Ann. Surg.*, 1945, *121:* 872–881.
10. Dockerty, M. B., Ghormley, R. K., Kennedy, R. L. J., and Pugh, D. G. Albright's syndrome (polyostotic fibrous dysplasia with cutaneous pigmentation in both sexes and gonadal dysfunction in females). *Arch. intern. Med.*, 1945, *75:* 357–375.
11. Dyke, C. G. The roentgen-ray diagnosis of diseases of the skull and intracranial contents. In: *Nelson's diagnostic roentgenology.* New York: T. Nelson & Sons, 1941, *1:* 1–34.
12. Echlin, F. Cranial osteomas and hyperostoses produced by meningeal fibroblastomas. A clinical pathologic study. *Arch. Surg., Chicago*, 1934, *28:* 357–405.
13. Eden, K. C. The benign fibro-osseous tumours of the skull and facial bones. *Brit. J. Surg.*, 1939, *27:* 323–350.
14. Elmslie, R. C. Discussion on fibrocystic disease of bone. *Proc. roy. Soc. Med.*, 1934, *27:* 973–975.
15. Etter, L. E., and Hurst, J. W. Polyostotic fibrous dysplasia. *Radiology*, 1943, *41:* 70–74.
16. Fairbank, H. A. T. Fibrocystic disease of bone. *J. Bone Jt. Surg.*, 1950, *32-B:* 403–423.
17. Falconer, M. A., Cope, C. L., and Robb-Smith, A. H. T. Fibrous dysplasia of bone with endocrine disorders and cutaneous pigmentation (Albright's disease). *Quart. J. Med.*, 1942, n.s. *11:* 121–154.
18. Ford, F. R. Diseases of the nervous system in infancy, childhood and adolescence. *Springfield, Ill.: Charles C Thomas*, 1944, 2nd ed., 1143 pp.
19. Freund, E. Osteodystrophia fibrosa unilateralis. Report of a case. *Arch. Surg., Chicago*, 1934, *28:* 849–866.
20. Freund, E., and Meffert, C. B. On the different forms of non-generalized fibrous osteodystrophy. *Surg. Gynec. Obstet.*, 1936, *62:* 541–561.
21. Furst, N. J., and Shapiro, R. Polyostotic fibrous dysplasia: review of the literature with two additional cases. *Radiology*, 1943, *40:* 501–515.
22. Geschickter, C. F., and Copeland, M. M. Tumors of bone. *Philadelphia: J. B. Lippincott Co.*, 1949, 3rd ed., xviii, 810 pp.
23. Gorham, L. W., Campbell, E. H., Howard, W. P., Donhauser, J. L., and Rust, N. H. Albright's syndrome. A group of cases characterized by osteitis fibrosa disseminata, areas of pigmentation and a gonadal dysfunction. *Clinics*, 1942, *1:* 358–385.
24. Helfet, A. J. A new conception of parathyroid function and its clinical application. A preliminary report on the results of treatment of generalized fibrocystic and allied bone diseases and of rheumatoid arthritis by aluminium acetate. *Brit. J. Surg.*, 1940, *27:* 651–677.
25. Jaffe, H. L. Fibrous dysplasia of bone. A disease entity and specifically not an expression of neurofibromatosis. *J. Mt. Sinai Hosp.*, 1945, *12:* 364–381.
26. Jaffe, H. L. Fibrous dysplasia of bone. *Bull. N.Y. Acad. Med.*, 1946, *22:* 588–604.

27. JAFFE, H. L. Personal communication.
28. KANAVEL, A. B. Surgical intervention in leontiasis ossea. A study of the clinical histories and skulls in relation to curative and palliative operations, with the report of a case. *Surg. Gynec. Obstet.*, 1907, *4:* 719–734.
29. KNAGGS, R. L. Leontiasis ossea. *Brit. J. Surg.*, 1923, *11:* 347–379.
30. LANGE, K. Zur Ostitis fibrosa generalisata (Recklinghausen). *Zbl. Chir.*, 1938, *65:* 2368–2373.
31. LICHTENSTEIN, L. Polyostotic fibrous dysplasia. *Arch. Surg., Chicago*, 1938, *36:* 874–898.
32. LICHTENSTEIN, L., and JAFFE, H. L. Fibrous dysplasia of bone. A condition affecting one, several or many bones, the graver cases of which may present abnormal pigmentation of skin, premature sexual development, hyperthyroidism or still other extraskeletal abnormalities. *Arch. Path.*, 1942, *33:* 777–816.
33. MACCARTY, C. S., and GOGELA, L. J. Meningioma of the sphenoid ridge in a child. *J. Neurosurg.*, 1949, *6:* 182–186.
34. MCCUNE, D. J., and BRUCH, H. Osteodystrophia fibrosa. Report of a case in which the condition was combined with precocious puberty, pathologic pigmentation of the skin and hyperthyroidism, with a review of the literature. *Amer. J. Dis. Child.*, 1937, *54:* 806–848.
35. MOEHLIG, R. C., and SCHREIBER, F. Polyostotic fibrous dysplasia. Report of a case with unilateral involvement. *Amer. J. Roentgenol.*, 1940, *44:* 17–23.
36. NELLER, J. L. Osteitis fibrosa cystica (Albright). *Amer. J. Dis. Child.*, 1941, *61:* 590–605.
37. OPPENHEIM, H. Lehrbuch der Nervenkrankheiten für Ärzte und Studierende. *Berlin: S. Karger*, 1913, 6th ed., *2.*
38. PAGET, J., FRICKER, G., and VER BRUGGHEN, A. Osteitis fibrosa cystica localisata of the skull. *J. Neurosurg.*, 1950, *7:* 447–450.
39. PECK, F. B., and SAGE, C. V. Diabetes mellitus associated with Albright's syndrome (osteitis fibrosa disseminata, areas of skin pigmentation, and endocrine dysfunction with precocious puberty in females). *Amer. J. med. Sci.*, 1944, *208:* 35–46.
40. PFEIFFER, R. L. Roentgenography of exophthalmos with notes on the roentgen ray in ophthalmology. *Trans. Amer. Ophthal. Soc.*, 1941, *39:* 492–560.
41. PROFFITT, J. N., MCSWAIN, B., and KALMON, E. H., JR. Fibrous dysplasia of bone. *Ann. Surg.*, 1949, *130:* 881–895.
42. PUGH, D. G. Fibrous dysplasia of the skull: a probable explanation for leontiasis ossea. *Radiology*, 1945, *44:* 548–555.
43. REESE, A. B. Orbital tumors and their surgical treatment. *N.C. med. J.*, 1940, *1:* 583–592.
44. RUSSELL, L. W., and CHANDLER, F. A. Fibrous dysplasia of bone. *J. Bone Jt. Surg.*, 1950, *32-A:* 323–337.
45. SCHLUMBERGER, H. G. Fibrous dysplasia of single bones (monostotic fibrous dysplasia). *Milit. Surg.*, 1946, *99:* 504–527.
46. SNAPPER, I. Medical clinics on bone diseases. A text and atlas. *New York: Interscience Publishers, Inc.*, 1949, 2nd ed., xii, 308 pp.
47. SOSMAN, M. C. Discussion of paper by Pugh, D. G.[42] *Radiology*, 1945, *44:* 555.
48. STAUFFER, H. M., ARBUCKLE, R. K., and AEGERTER, E. E. Polyostotic fibrous dysplasia with cutaneous pigmentation and congenital arteriovenous aneurysms. *J. Bone Jt. Surg.*, 1941, n.s. *23:* 323–334.
49. STERNBERG, W. H., and JOSEPH, V. Osteodystrophia fibrosa combined with precocious puberty and exophthalmic goiter. Pathologic report of a case. *Amer. J. Dis. Child.*, 1942, *63:* 748–783.
50. SUMMERFELDT, P., and BROWN, A. Osteodystrophia fibrosa. *Amer. J. Dis. Child.*, 1939, *57:* 90–101.
51. THANNHAUSER, S. J. Neurofibromatosis (von Recklinghausen) and osteitis fibrosa cystica localisata et disseminata (von Recklinghausen). A study of a common pathogenesis of both diseases. Differentiation between "hyperparathyroidism with generalized decalcification and fibrocystic changes of the skeleton and osteitis fibrosa cystica disseminata." *Medicine, Baltimore*, 1944, *23:* 105–148.
52. WARRICK, C. K. Polyostotic fibrous dysplasia—Albright's syndrome. A review of the literature and report of four male cases, two of which were associated with precocious puberty. *J. Bone Jt. Surg.*, 1949, *31-B:* 175–183.
53. WELLS, P. O. Fibrous dysplasia of bone (monostotic). *Radiology*, 1949, *52:* 642–654.
54. WINDHOLZ, F. Cranial manifestations of fibrous dysplasia of bone. Their relation to leontiasis ossea and to simple bone cysts of the vault. *Amer. J. Roentgenol.*, 1947, *58:* 51–63.
55. WINDHOLZ, F., and CUTTING, W. C. Leontiasis ossea. *Stanford med. Bull.*, 1945, *3:* 69–81.
56. WYATT, G. M., and RANDALL, W. S. Monostotic fibrous dysplasia. *Amer. J. Roentgenol.*, 1949, *61:* 354–364.

# VENTRICULO-URETEROSTOMY

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DRAINAGE of spinal fluid from the lumbar subarachnoid reservoir into the ureter by means of a small-calibre polyethylene tube was reported in the *Journal of Neurosurgery* in May, 1949.[1] This procedure has since been employed in all patients with progressive hydrocephalus in whom free communication between the ventricular system and the spinal subarachnoid space has been demonstrated, and in whom it has been felt that irreversible neurological deterioration has not occurred (29 patients).

At the Harvey Cushing Society Meeting in April, 1950, in the course of discussing the importance of adding salt to the diet of all infants who have had a shunt performed between the subarachnoid pathways and the urinary tract, mention was made of another operative procedure, ventriculo-ureterostomy, performed in patients who had obliteration of the spinal as well as the intracranial surface subarachnoid spaces. A number of subsequent inquiries concerning the indications, technique, and results of this procedure suggested that this brief report should be made.

The principal indications for diversion of spinal fluid from the ventricular system directly to some external surface are two:

(1) Obliteration of the surface subarachnoid pathways at the base of the brain, in the posterior fossa and in the spinal canal as an aftermath of generalized purulent meningitis bacteriologically cured by antibiotic therapy. This situation may arise in patients of any age, and may perhaps be expected with increasing frequency as patients with severe meningitis recover who formerly would have died during the acute phase of their infection.

(2) In benign obstructions of the aqueduct of Sylvius within the first few months of life, the surface subarachnoid pathways, particularly at the base of the brain, may also be obliterated, either because they have been involved in the same post-inflammatory process that has obstructed the aqueduct or because they have simply failed to develop since they have never had a normal amount of spinal fluid reaching them. In any case, third ventriculostomy by the subfrontal or subtemporal route and ventriculo-cisternostomy (Torkildsen procedure) are of no avail because the surface pathways cannot handle the fluid even though the obstructed aqueduct may be successfully by-passed.

The operation of ventriculo-ureterostomy is performed as follows: The patient is placed on the operating table in the lateral position as for a nephrectomy. The entire flank, lumbar, thoracic, cervical and occipital regions are prepared and draped as a sterile field. A standard subcostal nephrectomy

incision is made, the muscles are divided in turn, the false renal capsule is entered and the kidney mobilized. The ureter is identified and divided at its junction with the renal pelvis in such a way as to leave its nerve and blood supply intact. The vessels of the renal pedicle are divided between ligatures and the kidney is removed. The wound is left open.

Next a burr hole is made in the posterior temporo-occipital area and the dura incised. A silk suture is placed in either margin of the dura. A 2 cm. incision through the skin is then made about 2 cm. lateral to the mid-line

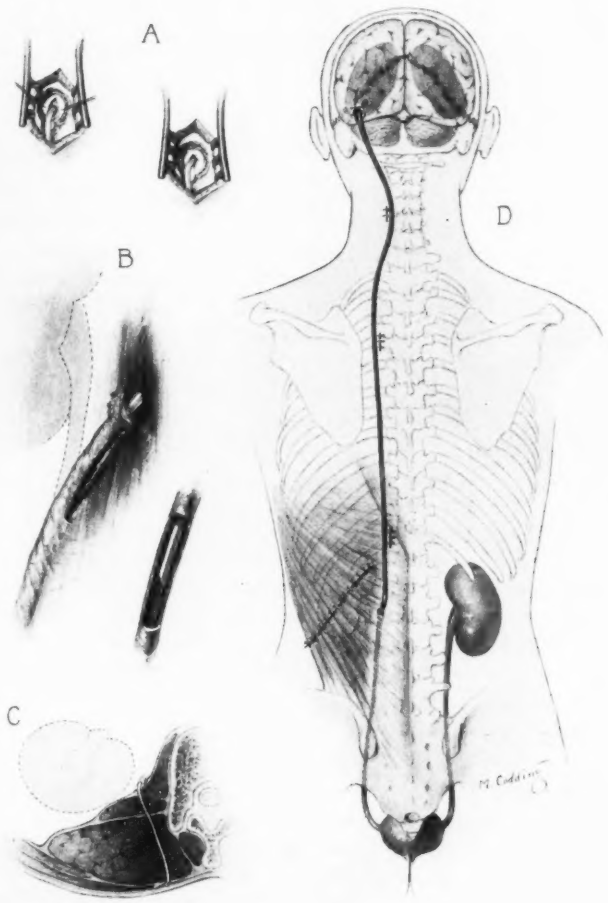


FIG. 1. (A) Detail of burr hole and secure attachment of tube to the dura. (B) Detail of insertion of tube into the ureter. (Modified from Fig. 5, Matson.[1]) (C) Pathway of the tube from subcutaneous to retroperitoneal space. (D) General plan of ventriculo-ureterostomy.

low in the cervical region; a similar incision is made over the 12th rib, and one or more in between these two. A zephiran-sterilized length of polyethylene tubing is passed from one incision to another through subcutaneous tunnels made by passage of a full-length clamp.

Approximately 5–7 cm. of the tube is introduced into the lumen of the lateral ventricle along the track made by a ventricular cannula. It is wise to bend the polyethylene catheter to a gentle right angle at the appropriate point before introduction into the ventricle by dipping it in very hot saline solution and allowing it to cool in the desired position. The silk sutures on the dural margins are secured around the tubing (Fig. 1A). From the lowermost stab incision, over the 12th rib, the tubing is tunnelled through the paraspinal muscles in a smooth curve to the retroperitoneal space (Fig. 1C).

When a free flow of ventricular fluid has been established through the tube, approximately 6 cm. of it is introduced into the lumen of the ureter. Sutures in the edge of the ureteral orifice are used to anchor it to the fascia of the paraspinal muscles (Fig. 1B). No ligatures are placed around the ureter at any point. The size tubing used has been that which receives a #18 intravenous needle snugly into its lumen. An effort is made to place the tube while the neck and back are in a position of maximum flexion.

This operation has been performed without mortality, infection or other postoperative complications in 4 patients. In each instance there was markedly increased intracranial pressure pre-operatively and in each instance the pressure has been normal or low from the moment the operation was completed. These patients have now been followed for 2, 4, 8 and 15 months. There has been no evidence of meningitis, tissue reaction to the long polyethylene tube, or recurrent increased pressure. The 3 infants have been given 2 gm. of added table salt per 24 hours.

The obvious problem with this procedure in infants and young children is that of growth. If new pathways for circulation and absorption of spinal fluid do not develop as growth proceeds, the tube will need to be replaced when it becomes too short. If a majority of growth has already been achieved there is no reason why such a ventriculo-ureteral shunt should not function indefinitely. This operation should be performed in situations where continuous external drainage of spinal fluid is the only possible successful form of treatment. It may serve as a palliative procedure in the presence of neoplasm or as a permanent shunt in benign, inoperable forms of obstruction to the surface subarachnoid pathways.

Abbreviated case reports follow.

*Case 1.* L.L. was admitted at the age of 4 weeks because of fever, vomiting and irritability. Studies revealed staphylococcus meningitis which responded poorly but eventually to antibiotic therapy. It was then noted that the baby had a small soft tissue mass and dimple in the mid-line of the occipital region, and x-rays revealed a minute defect through the bone. In November, 1948 a dermoid inclusion cyst in the scalp, together with a tract extending through the bone and down between the layers of the dura where it seemed to terminate, were excised.

The patient was readmitted in February, 1949 because her head had grown in size too rapidly in the previous month and she had begun to vomit. Ventriculogram revealed obstruction in the 4th ventricle, so posterior fossa exploration was performed. Another small dermoid inclusion cyst was found in the right cerebellar hemisphere. However, the principal pathology was complete obliteration of the cisterna magna, the outlets of the 4th ventricle and the entire surface subarachnoid pathways over the cerebellum and upper spinal cord by intense adhesive arachnoiditis. The cerebellar vermis was split and the 4th ventricle opened as widely as possible. Since the aqueduct and 4th ventricle were patent, a Torkildsen procedure was not performed.

The patient did well postoperatively, but her head continued to enlarge. Right choroid plexectomy was therefore performed, and 6 weeks later, left choroid plexectomy as well. Repeated attempts to obtain spinal fluid by lumbar puncture during this period were unsuccessful. Following these procedures, increased intracranial pressure recurred again after a few weeks. It seemed apparent that this baby did not form spinal fluid very rapidly, but that virtually none of it was being absorbed. This was confirmed by dye studies. Ventricular puncture was performed every 4–6 days for 2 months in the out-patient department with removal of 75–100 cc. of fluid without improvement (Fig. 2). She was therefore readmitted and left ventriculo-ureterostomy was performed in September, 1949. The tube was readjusted and anchored more securely at the level of the burr hole 2 weeks later. Following this the patient did very well, her pressure has since remained continually low, and she has not had to be tapped again in the 15 months since operation.

FIG. 2. *Case 1.* Ventricular "bubble" study showing extent of the hydrocephalus at the time of ventriculo-ureterostomy.

It has been hard to sort out in this patient how much damage there may have been from the staphylococcus meningitis which was so difficult to control in the first few weeks of life, and how much from the long continued increased intracranial pressure temporarily lessened by various operative procedures and taps and finally permanently relieved by ventriculo-ureterostomy. She is an only child of parents who can have no others, and in spite of considerable doubt as to her vision and eventual developmental possibilities before ventriculo-ureterostomy, this was pursued at the parents' request. They have been gratified. The child is happy, alert, very responsive, eats well and is still improving steadily. At 25 months, she crawls, sits, but cannot yet stand or walk alone. She has very pale optic discs, but can see well enough to play with toys normally and recognize people across the

room. She says quite a number of words. Her future progress will be followed with interest (Fig. 3).

*Case 2.* C.M. was first seen at The Children's Hospital in May, 1946 at the age of 10 because of headache and vomiting. Ventriculography disclosed obstruction of the aqueduct of Sylvius presumably due to a mass lesion which produced a filling defect in the posterior portion of the 3rd ventricle. Posterior fossa exploration proved negative and a Torkildsen procedure was performed.

In April, 1947 the patient was readmitted because of vomiting, pain in the right eye, diplopia, easy fatiguability and unsteadiness of gait. A right subtemporal decompression was performed after repeat ventriculogram had demonstrated increase in size of the ventricles with persistence of the mass in the posterior portion of the 3rd ventricle. Following this, 3000 R of roentgen therapy were directed to the posterior 3rd ventricle with symptomatic improvement.

FIG. 3. *Case 1.* Appearance of patient at 2 years of age, 14 months after ventriculo-ureterostomy.

In November, 1949, at the age of 14, patient was admitted to the Peter Bent Brigham Hospital because of drowsiness, weakness, staggering gait, and increasing strabismus. He was intelligent and cooperative but lapsed into a lethargic state when not aroused. His gait showed marked weakness and ataxia. His subtemporal decompression bulged and his optic disc margins were obliterated. There was a marked internal squint and limitation of upward gaze. Ventriculogram revealed a continued increase in the degree of hydrocephalus. The aqueduct appeared to be blocked, and this was confirmed on dye studies.

The Torkildsen tube was explored and readjusted in the ventricle and in the posterior fossa. There was no improvement so subsequently this tube was removed and a Torkildsen tube placed on the opposite side from the lateral ventricle to the region of the lateral cistern. At this time it was apparent that the entire posterior fossa was filled with many arachnoidal adhesions. The patient continued to show increasingly elevated ventricular pressure until unless it was reduced every 8–12 hours he would lapse into coma with respiratory difficulty.

It was felt that due to the meningeal adhesions, external drainage directly from the ventricular system was essential for symptomatic relief regardless of the course of the primary lesion, so left ventriculo-ureterostomy was performed in January, 1950. Postoperative course was complicated by two generalized convulsions on the 5th day when the patient first sat upright. He was therefore kept flat until the 14th day and then gradually gotten up. His spinal fluid pressure remained low at all times. He was alert, cheerful, asymptomatic, had a good appetite and walked rather unsteadily with support at the time of discharge a month after operation.

For about 6 months he continued to improve. His appetite was good, there was

no headache or vomiting, his decompressions remained soft, and his ataxia was much less. He continued to have paralysis of upward gaze. He then went down hill quite rapidly, developing extreme weakness, lack of appetite, intermittent stupor and finally slipping into coma with eventual respiratory failure. At no time did he complain of headache, nausea, vomiting, or show any evidence of increased pressure or infection. He died at home and an autopsy was not performed.

It is felt that this patient had an inoperable neoplasm in the posterior 3rd ventricle. After failure of a Torkildsen procedure to continue functioning, ventriculo-ureterostomy effectively alleviated the symptoms of increased intracranial pressure until death.

*Case 3.* M.T. was delivered at term by Caesarian section because of cephalo-pelvic disproportion. The head was noted to be large at birth but the fontanelles were depressed and the sutures overlapping. The baby did well and the head did not increase in size until between the 8th and 11th weeks of life, when it grew about 3 cm. in circumference. At that time, the head measured 52 cm., the anterior fontanelle was bulging slightly, the sutures were separated, the scalp veins were dilated, and there was an internal strabismus with downward displacement of the eyes.

Hydrodynamic and dye studies showed no communication between the ventricular and lumbar spaces and ventricular air studies were consistent with an aqueductal obstruction. Posterior fossa exploration revealed a small 4th ventricle with undeveloped surface subarachnoid pathways. A Torkildsen procedure was carried out. This proved unsatisfactory and 3 weeks later a right choroid plexectomy was performed. The head continued to enlarge and a week later left choroid plexectomy was done.

The patient was discharged from the hospital but readmitted approximately 2 weeks later because the head had started to increase in size again and was now up to 57 cm. Left ventriculo-ureterostomy was therefore carried out in July, 1950. Postoperative course was uneventful. The wounds healed well, the fontanelle remained depressed and the sutures overlapped. He was discharged on the 9th postoperative day. The head decreased in circumference by 2.5 cm.

The baby's development immediately accelerated rapidly. Four months after operation the head measured 55.5 cm.; the baby was alert, active, eating well, had normal neurological findings, and seemed to be improving steadily.

*Case 4.* J.A. was delivered by Caesarean section 2 weeks before term because of cephalo-pelvic disproportion. In the first month of life it was noted that the head increased in size very rapidly. At 4 weeks of age the head measured 41.6 cm. and the chest 31.2 cm. The anterior fontanelle was tense and distended, and there was palpable separation of the cranial sutures. The infant nursed well and gained steadily. Extra-ocular movements were normal. Deep tendon reflexes were equal and active.

On combined ventricular and lumbar tap there was no manometer or dye evidence of communication. Only 12.5 per cent of the dye was excreted in the urine in 12 hours. Ventricular air studies revealed extreme dilation of the lateral and 3rd ventricles but no air passing into the 4th ventricle.

Posterior fossa exploration was performed, revealing an undeveloped cisterna

magna, small 4th ventricle, undeveloped spinal subarachnoid space and apparently complete obstruction of the aqueduct. A Torkildsen procedure was carried out. Postoperative course was uneventful. The head became 1.6 cm. smaller and the fontanelle remained depressed, so the baby was sent home in 10 days.

Three and a half weeks later the baby was readmitted because the head had grown to 45.9 cm., the fontanelle was tense, and the sutures again were widely separated. In view of the previous operative findings, it was felt that a Torkildsen tube or 3rd ventriculostomy never would function in this infant due to the underdevelopment of the cisternae and surface subarachnoid pathways. Therefore, the Torkildsen tube was removed and a left ventriculo-ureterostomy performed in October, 1950. This patient happened to have a double ureter so that it was possible to leave the kidney in draining by one ureter and to use the other for receiving the plastic tube.

Postoperative course was uneventful. Wounds healed well, the head became 2.5 cm. smaller in circumference, the fontanelle remained depressed and the sutures overlapped. The baby has eaten well, gained steadily, is very active and alert and seems to be normal neurologically during the short follow-up period so far of 2½ months.

## SUMMARY

In patients with obstruction of the aqueduct or 4th ventricle and of the surface subarachnoid pathways as well, it is necessary to shunt spinal fluid directly from the lateral ventricles to some distant absorptive or excretory surface. This has been accomplished by ventriculo-ureterostomy using a long, small-calibre polyethylene tube passed in the subcutaneous space. The operation is simple, and has been uniformly successful in 4 patients in completely relieving increased intracranial pressure without infection, foreign-body reaction or other serious complication for follow-up periods to date of 2 to 15 months. It is suggested that this procedure may be particularly appropriate to older patients in whom the subarachnoid pathways have been generally obliterated either by a pyogenic or some aseptic meningeal reaction.

## ADDENDUM

Since the preparation of this report, ventriculo-ureterostomy has been performed on 3 additional infants. In these patients, as well as the 3 living children reported here, satisfactory relief of intracranial pressure has been maintained and they are developing well.

## REFERENCE

1. Matson, D. D. A new operation for the treatment of communicating hydrocephalus. Report of a case secondary to generalized meningitis. *J. Neurosurg.*, 1949, *6:* 238–247.

# PREFRONTAL LOBOTOMY FOR RELIEF OF PAIN

## WITH A REPORT OF A NEW OPERATIVE TECHNIQUE

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SINCE Freeman and Watts[4] reported that prefrontal lobotomy was useful as a method for relieving intractable pain, numerous reports[2,5,6,7,9,11,12] have attested to the success of the operation in cases of intractable pain not curable by direct attack on the primary disease process. Not only is the fear of suffering abolished, but many patients no longer have pain in the usual sense of that word. The conventional (radical) prefrontal lobotomy, however, has distinct disadvantages, chief of which are changes in personality. Another disadvantage is the high incidence of epilepsy following the currently employed operations. These alterations are grave enough to limit the use of the procedure to a relatively small group of patients suffering with intractable pain.

Probably all surgeons who have performed prefrontal lobotomy for pain have envisaged that with greater experience a wide field may be opened for its usefulness. If this is to be accomplished, however, an operation resulting in less unwanted side effects must be perfected. Such a procedure should accomplish a selective or limited destruction of the frontal lobes as contrasted to the extensive destructive lesion produced by conventional methods. To develop a selective prefrontal lobotomy the fiber tracts (or cortical areas) controlling the function to be destroyed must be accurately known. It is also necessary that a method be devised to reach this limited area for destruction without damaging other important areas in the process of reaching and destroying the selected area. If, on the other hand, the results of lobotomy are in direct proportion to the quantity of tissue destroyed, then the proportion of the frontal lobes to be destroyed for a specific result must be known.

After operating on psychiatric patients by the open method of Lyerly,[8] the writer varied the procedure to one in which an effort was made to divide only the white matter in the medial half of the frontal lobe rostral to the lateral ventricle. The results after this procedure were as gratifying as they were in the cases of more extensive incisions. The same operation also was successful in several cases performed for the relief of pain. Consideration of these facts plus a desire to produce a destructive lesion by a fractional method brought to mind the possibility of performing prefrontal lobotomy by electrocoagulation. The lesions are produced by a high frequency electrical current applied through a small needle insulated everywhere except at the tip. By this method a small lesion can be produced in any portion of

the frontal lobes and the desired area can be approached and destroyed without damage to other areas of the hemisphere. In the same manner the lesion may be increased in size if subsequent study of the patient indicates that a larger incision is needed.

## TECHNIQUE

The operation may be performed under local or general anesthesia. A coronal incision 10 cm. in length is made just behind the hairline. A point approximately 6 cm. above the glabella is selected and marked on the exposed frontal bone. A burr hole is made at this level over each frontal lobe. The distance of the burr hole from the midline varies according to which portion of the white matter of the frontal lobe is to be destroyed. The center of the burr hole is 1.5–2 cm. from the midline if the lesion is to be made in the white matter of the medial half of the hemisphere, as was done on the patients included in this report. The dura is opened in a cruciate fashion. In some patients, instead of a burr-hole exposure, a 1-inch trephine has been used so that the medial surface of the hemisphere could be visualized. When the trephine opening is employed, the dura should be opened carefully to avoid damage to a vein, which is sometimes exposed, leading to the sagittal sinus. For identification of the proper plane for the electrode, a point is marked in the temple 2 cm. behind the lateral rim of the orbit. A scratch mark made on the scalp between the burr hole and the point 2 cm. behind the rim of the orbit is used in selecting the plane for the electrode. In most instances, with the burr holes at 6 cm. above the glabella, a ventricular needle, which is used to make a path for the electrode, will

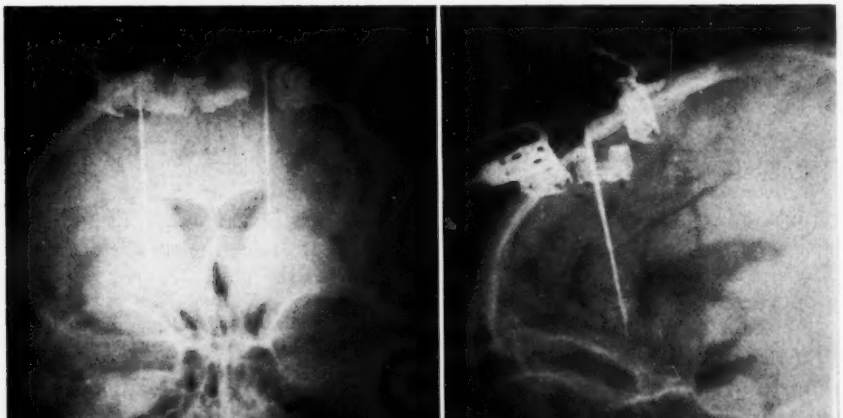

FIG. 1 (*left*). An anteroposterior x-ray shows the correct placement of the electrodes in relation to the sagittal plane and the anterior horns of the lateral ventricle. In this instance, the electrodes are at a depth of 4.5 cm. below the surface of the cortex and lie 2 cm. from the midline.

FIG. 2 (*right*). A lateral x-ray shows the two electrodes in the same plane and at the proper distance rostral to the anterior horn of the lateral ventricle.

pass in front of the anterior horn of the lateral ventricle when directed at the point 2 cm. posterior to the lateral rim of the orbit. To be certain, however, that such is the case, the lateral horn of one or both lateral ventricles is deliberately tapped by passing the ventricular needle slightly posterior to this plane. At this time 10 cc. of ventricular fluid are removed and replaced with oxygen. The ventricular needle is then passed in a plane farther forward until it lies approximately 1 cm. anterior to the ventricle. A new line is then drawn on the scalp if the plane of the ventricular needle lies in a position different from that of the original scratch mark. The ventricular needle is then gently passed towards the floor of the skull to verify the depth of the frontal lobe at this point. In our experience the brain at this point is between 7 cm. and 8 cm. in depth. The electrode is then introduced along the path made by the ventricular needle, and the previously made scratch mark on the scalp is used to be certain that the electrode does not vary from this plane in an anterior or posterior direction. Equal care must be taken to be certain the electrode does not drift toward the midline. To make certain of this, a ribbon retractor is held by an assistant with the center of the retractor against the vertex of the skull. The operator makes certain that the advancing electrode is always at right angles to the retractor. If the lesion is to be made in the lower medial quadrant, the electrode is introduced to a depth 2 cm. short of the depth of the brain. If the frontal lobe at this point is 8 cm. in thickness, the insulated needle is passed to a point 6 cm. below the surface of the cortex. The procedure is carried out on the opposite hemisphere by introducing an electrode in an identical plane, after first providing a pathway with the ventricular needle.

At this point in the operation the position of the electrodes is checked with a portable x-ray. Before the head is draped, a loaded casette placed beneath the head is ready to verify the relationship of the electrodes to the sagittal plane and the anterior horn of the ventricle, which has previously been filled with oxygen (Fig. 1). Another casette dropped into a sterile pillow case is then used to make a lateral film which will record whether the electrodes are at the proper position rostral to the anterior horn of the lateral ventricle (Fig. 2). The position of the needles can be changed and rechecked with x-ray, but this will rarely be necessary if the above steps at identification are carefully followed.

The electrode is insulated except for 1 cm. of the tip, which is exposed.* The insulated portion is 2 mm. in diameter. Electrocoagulation is carried out by application of the current to the exposed connection at the free end of the needle. With the Davis-Bovie automatic-gap electrosurgical apparatus, a power setting of 20 on the coagulation device applied for 30 seconds will produce a lesion in this relatively avascular area of the brain in the form of a cylinder which will measure approximately 12 mm. in length and 8 mm. in diameter. To verify this fact, gross tests were made on excised pieces of tissue and in the intact animal brain. It is appreciated that there will be variations in the size of the lesion, depending on the vascularity of the tissue and the slight variation in the amount of current produced by the machine at different applications, but it is felt that such variation in the size of the lesion will be not over a few mm. and therefore inconsequential. A convenient method for testing the power setting of the machine at the time of surgery is to use one of the triangular flaps of dural tissue or a bit of exposed periosteum. With the tissue grasped in the tips of a fine tooth bayonet forceps, there should be charring of the tissue in 3 seconds after the current is applied to the forceps. The electrode is withdrawn 1 cm. for a second application of the current if a

* The electrode was made by the Liebel-Flarsheim Company of Cincinnati, Ohio.

large lesion is to be produced in the lower quadrant. Withdrawal and application of the current is continued, depending on the size of the lesion that is desired.

## REPORT OF CASES

The procedure was originally used on patients with advanced carcinoma who suffered intractable pain. Many of these early patients lived only a few weeks but the gratifying relief of pain and narcotic addiction and the absence of any detectable mental changes or other complications were so encouraging that the operation was then used on a few patients in whom the relief of pain of non-cancerous origin presented a difficult problem.

Since March, 1949 the operation has been performed 35 times in 22 patients. In 2 patients the operation has been performed in three stages and in 9 patients in two stages. In successive operations, the current was applied at a more dorsal depth. In most instances several weeks were allowed to elapse before a more extensive procedure was performed. In 1 patient, a tabetic, a unilateral procedure was satisfactory for 10 months, at which time severe pains recurred and the operation was then performed in the other hemisphere with relief of pain.

Thirteen patients had cancer, 1 tabetic crisis and 1 a thalamic syndrome. Seven patients had profound long-standing disability from pain considered to be of psychogenic origin. One patient with carcinoma of the throat died 22 hours following surgery without fully regaining consciousness. Autopsy was not obtained. Of the 21 patients who survived, in 19 (90 per cent) the operation has been successful to date, or for the time the patient lived following the procedure. In 2 cases the procedure was a failure in that the patients have continued to complain bitterly of pain.

To simplify an expression of the results, we have classified them into 5 grades as follows:

Grade 0—No improvement.
Grade 1—Relieved of addiction but complains spontaneously of pain.
Grade 2—Does not complain spontaneously of pain but will state that pain is present if questioned about pain.
Grade 3—Patient denies pain. Has no change in personality.
Grade 4—Relieved of pain but personality changes are present.

The desired result is either a Grade 2 or Grade 3. In the 21 patients who have lived, 14 patients (66.7 per cent) have been classed in Grade 2 or Grade 3 and the result has been considered near perfect. Two patients (9.5 per cent) have had a Grade 4 result, but the changes in personality were not significant enough to detract from the good results. In both of the patients who had personality changes, 3 operations were done before pain was relieved satisfactorily and autopsy revealed that the lesion involved virtually all the white matter of the medial half of the hemispheres. Three patients (14.3 per cent) have been relieved of their severe pain but still complain spontaneously—Grade 1. Two patients (9.5 per cent) had no benefit and a second procedure was not permitted.

In all of the cases, except the patient who died, there has been a prompt

recovery of consciousness following anesthesia. Slight mental confusion was noted in 2 patients for 24 hours. In 3 patients operated on with local anesthesia there was no confusion but mild drowsiness for a few hours. The temperature usually rises to 101° or 102° F within the first 24 hours and is thereafter normal. No other abnormal changes have been noted in physiologic processes. Several patients have had extensive psychometric evaluation before and after surgery and no changes have been detected.

## DISCUSSION

The original plan in performing the operation by the coagulation technique was to make lesions that were confined to the fibers in the medial half of the hemisphere. The intention was to produce lesions in the lower medial quadrant at the original operation, and in the event the results were not entirely satisfactory then at a second operation a lesion would be made in the upper medial quadrant. This is the method that has been used in all of the cases included in this report. If one visualizes the coronal section of the frontal lobe as consisting of four quadrants, it is obvious that a variety of combinations can be investigated in the search for minimal-size lesions that would produce the desired effects. The present feeling from the study of the cases done so far is that the lesion placed in the lower medial quadrants may be effective, but it is also felt that the larger lesions which have extended into the upper quadrant have been most successful in relieving pain. In future operations it is planned to make lesions in other quadrants for comparison with the cases presented here. It is of interest that the 2 patients who had distinct personality changes following operation had a larger lesion in the lower medial quadrant than the other patients who have come to autopsy.

Radiographic verification of the position of the electrodes in their relation to the anterior horns of the lateral ventricles affords precise information as to the location of the lesion. Variation in the position and size of the anterior horns alone emphasizes the necessity of the radiographic identification in addition to the other precautions taken for localization.

Autopsy studies on several patients who died within 6 weeks of their original cancerous pathology showed an area of malacia in the white matter of the frontal lobe corresponding to the size that was planned at surgery. In 1 patient who lived 10 weeks following the operation, only a small area of softening persisted. It is anticipated from these cases that by 12 to 16 weeks all signs of the lesion produced by electrocoagulation in the frontal lobe white matter will have disappeared. The complete absence of any scarring 4 months after the application of heat destruction to the cortex of the monkey's brain was shown by Dusser de Barenne and Zimmerman[1] in 1935. In this interesting article they suggested the use of this method to neurosurgeons.

There are several features in the technique that may be improved in the future. The use of a special localizing device has been entertained but has not been considered necessary. It is felt that it would still be necessary

to verify the location of the electrode in its relation to the anterior horn of the lateral ventricle. It is possible that a more precise method can be evolved for the application of the heat to give even greater uniformity to the size of the lesion.

One advantage of the electrocoagulation method is its simplicity and ease in performance. Another advantage is the protection of the cortex from injury, thereby minimizing the possibility of postoperative epilepsy. Pool[10] has reported an incidence of 16 per cent in his cases of topectomy. Freeman[3] reports an incidence of 7 per cent of seizures in his patients who have been operated upon one time. This percentage increased to 20 per cent in those upon whom a second operation has been performed. To date we have had no incidence of an epileptic seizure in any of the patients operated upon by the coagulation technique. Seven patients have been followed for 15 months and an additional 3 patients have been followed for more than 9 months. The remaining patients died of their carcinoma between 3 and 16 weeks following surgery.

The last, and perhaps the greatest, advantage is the ability to produce a lesion in any portion of the frontal lobe with radiographic verification of the site of this lesion and the further ability to increase the lesion in a systematic manner in subsequent operations if these become necessary.

## SUMMARY

1. A new technique to perform a selective prefrontal lobotomy is described.

2. Preliminary study of the results in 22 patients treated by this technique for the relief of pain is presented.

## REFERENCES

1. Dusser de Barenne, J. G., and Zimmerman, H. M. Changes in the cerebral cortex produced by thermocoagulation. A suggestion to neurosurgery. *Arch. Neurol. Psychiat., Chicago*, 1935, *33:* 123–131.
2. Dynes, J. B., and Poppen, J. L. Lobotomy for intractable pain. *J. Amer. med. Ass.*, 1949, *140:* 15–18.
3. Freeman, W. Discussion on papers by Drs. Arnot and Greenblatt. *Arch. Neurol. Psychiat., Chicago*, 1950, *63:* 345.
4. Freeman, W., and Watts, J. W. Pain of organic disease relieved by prefrontal lobotomy. *Lancet*, 1946, *1:* 953–955.
5. Grantham, E. G. Frontal lobotomy for the relief of intractable pain. *South. Surg.*, 1950, *16:* 181–190.
6. Hamilton, F. E., and Hayes, G. J. Prefrontal lobotomy in the management of intractable pain. *Arch. Surg., Chicago*, 1949, *58:* 731–738.
7. Love, J. G., Petersen, M. C., and Moersch, F. P. Prefrontal lobotomy for the relief of intractable pain. *Minn. Med.*, 1949, *32:* 148–153; 157.
8. Lyerly, J. G. Transsection of the deep association fibers of the prefrontal lobes in certain mental disorders. *South. Surg.*, 1939, *8:* 426–434.
9. Otenasek, F. J. Prefrontal lobotomy for the relief of intractable pain. *Johns Hopk. Hosp. Bull.*, 1948, *83:* 229–236.
10. Pool, J. L. Prefrontal operations for the treatment of mental illness. *Ann. intern. Med.*, 1949, *31:* 424–428.
11. Poppen, J. L. Prefrontal lobotomy for intractable pain: case report. *Lahey Clinic Bull.*, 1946, *4:* 205–207.
12. Scarff, J. E. Unilateral prefrontal lobotomy with relief of ipsilateral, contralateral, and bilateral pain. A preliminary report. *J. Neurosurg.*, 1948, *5:* 288–293.

# DIODRAST STUDIES OF THE VERTEBRAL AND CRANIAL VENOUS SYSTEMS

## TO SHOW THEIR PROBABLE ROLE IN CEREBRAL METASTASES*

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THE incidence of cerebral metastases is increasing. In Cushing's series of verified intracranial tumors 3.2 per cent were of metastatic origin[9] but more recent reports variously state the incidence as being from 5 per cent to 20.5 per cent, depending in large part upon the source of material and the number of complete autopsies performed.[8] In a series of 1076 verified intracranial tumors reviewed by the writer the incidence of metastatic tumors was found to be 8.4 per cent. Often the various surgical and physical measures directed at the primary lesion are of necessity incomplete and although the subject gains in comfort and his years of life are extended, the possibility of the development of cerebral metastases before his death is increased.

Cerebral metastatic lesions are blood-borne since no lymphatics are present in the brain.[11,15] Moreover, their frequent multiplicity and widespread distribution throughout the brain attest to their vascular spread.[22] Frequently, the cerebral involvement is the only point of implantation secondary to a distant primary lesion. This is difficult to explain on a vascular basis and, although other factors are involved, it would seem that the simple mechanics of hematogenic spread of metastases should be considered first.

The commonly accepted route of the vascular spread of tumor cells to the brain is along the arterial tree. The fact that tumors of the lungs are among the largest contributors to cerebral metastases would support such a consideration since their position allows direct passage of tumor cells to the heart and thence to the brain via the arterial system.[7] The manner in which the pulmonary filter is bridged in cases of blood-borne material from the portal system, caval system and general circulation has not been easily explained. Hence the common expression "paradoxical embolism." Of course, instances of congenital heart lesions would answer this question, and cases of patent foramen ovale and ventricular septal defects associated with metastatic lesions have been described.[21]

However, cases of cerebral metastases secondary to pathology in the

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pelvis, or of the genito-urinary tract, in the absence of evidence of metastases to the lung and without patent foramen ovale or other congenital cardiac defects, would indicate that other modes of hematogenic spread must exist. Also, the spread of carcinoma of the breast to the brain in the absence of intrathoracic extension would indicate that other vascular routes are present.

Although Willis in 1664 and Bock in 1823 accurately described the vertebral and cranial venous plexuses[12] and although von Recklinghausen[17] in 1885 pointed out the phenomenon of retrograde venous metastases, it remained for Batson[5] in 1940 to postulate the role of the vertebral venous system in the spread of metastases. By the use of various radiopaque substances injected into the venous systems of human cadavers, he demonstrated roentgenologically the ease with which media could pass along the vertebral venous system, its close association with the veins of the body wall, pelvic and shoulder girdles and finally, its continuity with the venous sinuses within the cranium. Similar cadaver studies were repeated by Collis[6] in 1944 and he presented clinical evidence which implicated the vertebral venous system as a mode of spread of cerebral metastases complicating various forms of intrathoracic suppuration.

In 1941, Harris[12] reviewed previously known anatomical facts regarding the spinal and cranial venous systems and emphasized that the anatomical conditions were well documented but that the clinical pathological implications had not been recognized. Recent dissection studies by Anson *et al.*[2,3] with attention directed to the pararenal venous system have indicated the close relationship of this venous complex with the vertebral venous system. They pointed out the avenues of possible hematogenic migration through the renal, lumbar, intervertebral veins and vertebral plexuses to the spongious bone of the vertebrae; or, upward along the vertebral venous system to the dural or diploic veins of the cranium.

The pathological evidence that tumor cells in general tend to invade adjacent veins and that their venous spread is a common occurrence has been emphasized by Willis[22] and others. Further, it is known that venous emboli frequently move in a direction opposite to that of their usual flow. This is particularly true in the vertebral veins where there is an absence of valves.[6] There is a tendency toward stasis in the multiple sinuses of this system where there are frequent reversals of blood flow as a result of postural changes and variations in intrathoracic and intra-abdominal pressures.

By the employment of diodrast (3,5-diiodo-pyridone-N-acetic acid and diethanolamine) and newer injection techniques it was believed that (1) the cadaver experiments could be repeated and (2) that similar studies could safely be performed on living subjects to determine whether venous patterns obtained in cadaver studies would be found in the presence of normal circulating mechanisms. To this end, employing a 52½ per cent diodrast solution, a series of 12 cadaver studies were made and 22 injections in living humans were performed.

## METHODS AND RESULTS

### *Cadaver Experiments*

Twelve cadaver studies were performed. Ten specimens were injected through the deep dorsal penile vein after the method of Batson and in 2 instances the cephalic vein of the upper arm was utilized. All of the subjects were adult males who had died of a variety of causes but in whom there was

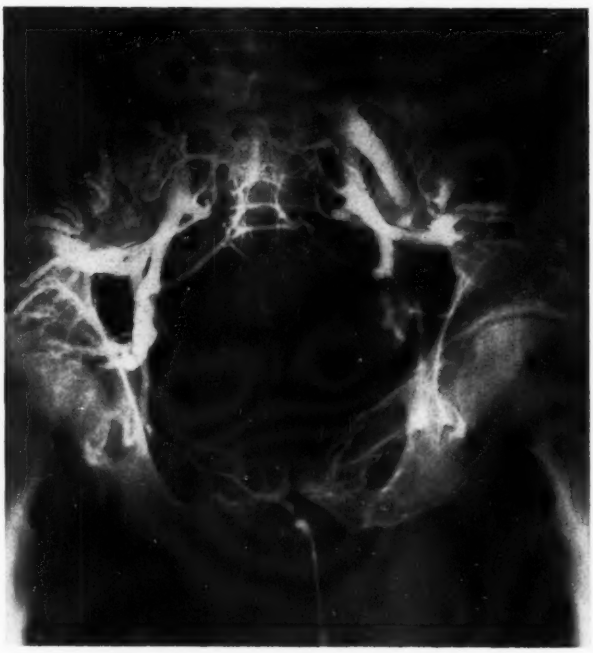

FIG. 1. Initial injection of diodrast into an adult male cadaver. The cannula is attached to the deep dorsal penile vein.

no evidence of vascular malformation, disease, or trauma that might have resulted in an abnormal venous filling.

Shortly after death the cadaver was placed on the dissecting table in the usual dorsal recumbent position. The diodrast solution was warmed prior to injection since it was found that this tended to prevent crystallization and enabled the plunger to move through the syringe smoothly. The deep dorsal vein of the penis was isolated just distal to the suspensory ligament of the pubis and a small cannula inserted. A 30 cc. syringe containing the diodrast was connected to the cannula and the injection was made slowly and at a constant rate. This required very little pressure; in fact when the butt of the syringe was elevated the weight of the plunger alone would often cause the diodrast to flow into the vein.

When 30 cc. of diodrast had been injected a roentgen film of the lumbar region and pelvis was exposed with a portable x-ray machine employing a stationary grid. A typical film is shown in Fig. 1, with the cannula in the dorsal penile vein. After 60 cc. more diodrast were injected a venous pattern was obtained (Fig. 2). These illustrations demonstrate the presence of the opaque media in the dorsal vein of the penis and its connections with the pudendal, prostatic and vesical plexuses. The pudendal veins, hypogastric

FIG. 2. Extensive filling of veins of the vertebrae, genito-urinary system and pelvic girdle.

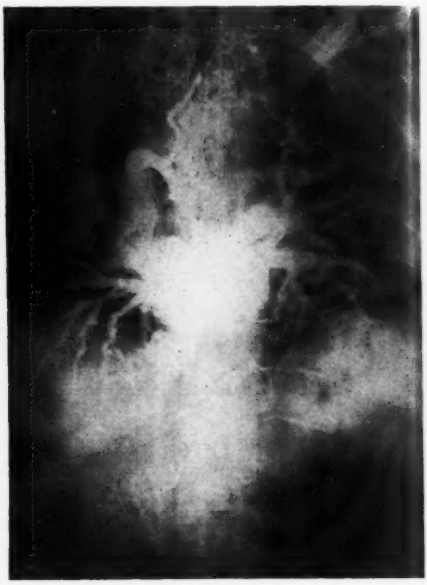

FIG. 3. Appearance of thoracic structures after injection of 150 cc. of diodrast into deep dorsal penile vein.

veins, obturator veins and iliac veins are well outlined and their numerous anastomoses are evident. The ascending lumbar veins and their rich segmental connections with the intervertebral veins and with the inferior vena cava are shown. The external vertebral veins and, to a lesser extent, the internal vertebral veins are also demonstrated. In the upper lumbar region there is extensive filling of the renal venous plexuses.

After another injection of 60 cc. of the diodrast into the deep dorsal vein of the penis a film of the thoracic region was made (Fig. 3). This shows the further ascent of the opaque media along the vertebral venous system with some filling of the inferior vena cava, the hepatic veins, the pulmonary veins, and the right auricle and ventricle.

In the lower thoracic region the segmental connections of the respective intercostal veins with the vertebral veins can be seen. In the upper portion

of the thorax on the right side the superior portion of the azygos vein is seen where it arches laterally to meet the superior vena cava, which is faintly outlined with a lesser concentration of diodrast. Extending superiorly from the medial aspect of the arch of the azygos vein is the supreme intercostal vein, which connects with the intercostal veins of the first three ribs on the right side. There is some filling of the deep cervical veins and the vertebral veins in the lower portion of the neck.

After a total of 200 cc. of the diodrast had been injected into the deep dorsal penile vein, skull films were obtained. In Fig. 4 there is an accumulation of the opaque media in the superior sagittal sinus and in addition the confluens sinuum is faintly outlined where the transverse sinuses blend into the sagittal sinus.

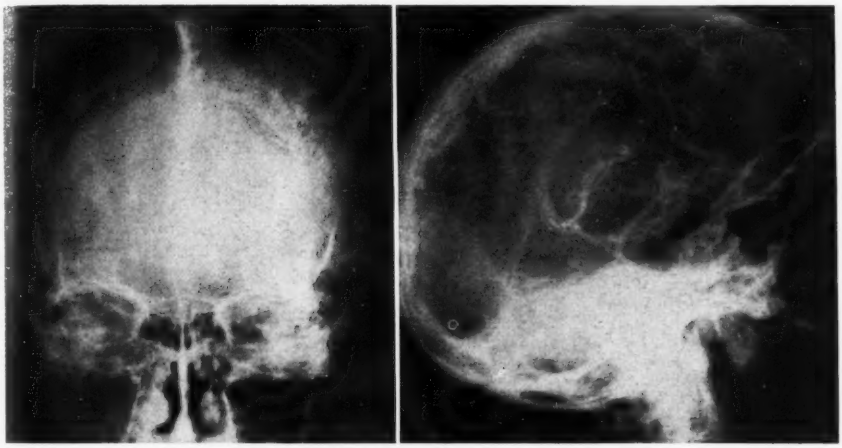

FIG. 4 (*left*). P-A film of skull showing diodrast in superior sagittal sinus.
FIG. 5 (*right*). Lateral film. There is extensive filling of the cranial sinuses and cerebral veins.

The lateral view (Fig. 5) demonstrates a heavy concentration of the opaque media in the superior sagittal sinus and many of the superior cerebral veins are filled and blend into the superior sagittal sinus. Beneath it the inferior sagittal sinus is clearly outlined although not as well defined because it is much smaller in size, particularly anteriorly. Posteriorly the straight sinus is well filled and can be visualized as it joins the two sagittal sinuses. The great cerebral vein, the petrosal sinuses and a portion of the basilar plexus of veins are outlined.

In order to visualize better the veins of the shoulder girdle, the breast, and the deep cervical veins, the cephalic vein was injected in the right upper arm just distal to the deltoid muscle where the vein courses along the lateral aspect of the biceps. In Fig. 6 the cephalic vein is outlined in the lower right-hand corner and can be seen curving downward and emptying into the large axillary vein. Following medialward a portion of the subclavian vein is not

visualized but inferiorly the azygos vein can be seen with its component, the supreme intercostal vein, extending upward. On the left side, at approximately the mid-clavicle, the descending left mammary vein can be seen. The transverse cervical vein is outlined on both sides of the neck, as are many of the scapular veins, which are most heavily filled on the side of the injection. On the right side, along the lateral margins of the cervical vertebrae, the deep cervical vein is well demonstrated. Laterally, and not as well filled, the internal jugular veins can be seen as they descend from just within

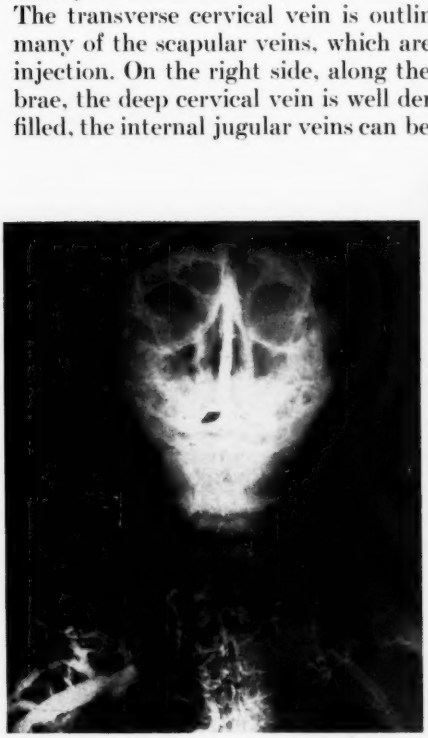

FIG. 6. Appearance of head, neck and upper thorax of an adult cadaver after injection of 90 cc. of diodrast into the cephalic vein of right upper arm.

FIG. 7. Normal filling of right femoral vein, iliac vein and inferior vena cava in a living subject.

the superimposed mastoid processes. Intracranially the sagittal sinus is well demarcated and the transverse sinuses can be seen joining it at their point of confluence.

### *Diodrast Injections in Patients*

The procedures were duplicated, in so far as was practicable, in human patients in the presence of normal circulating mechanisms. An exposure of the dorsal penile vein in these subjects was unwarranted; therefore, the injection was made percutaneously into the femoral vein just distal to the inguinal ligament. The advantage of this injection was that under proper conditions the connection between the systemic vessels in the pelvic and lumbar region with the vertebral venous system might be demonstrated.

In 1947 Fariñas[10] and O'Loughlin[16] separately described methods for roentgen visualization of the inferior vena cava with diodrast. The procedure employed in these studies is essentially a combination of their methods with some technical extensions to emphasize the collateral circulation. Femoral vein injections of diodrast were performed in 18 instances.

Prior to the injection of the 52½ per cent diodrast solution, an evaluation of the cardio-hepato-renal status was made and a skin test for drug idiosyncrasy was done. The patient was prepared as for an ordinary kidney-ureter-bladder study in which 35 per cent diodrast is employed. He was placed on the roentgen table in the supine position. The skin of the upper thigh and inguinal region was shaved and prepared

FIG. 8 (*left*). Abdominal compression has resulted in shunting of blood into the vertebral venous system.

FIG. 9 (*right*). Abdominal compression has resulted in shunting of blood into ascending lumbar vein and vertebral veins.

surgically with soap and water, and a 1 per cent ceepryn solution. A 1 per cent procaine solution was injected first as a skin wheal over the fossa ovalis midway between the anterior superior iliac spine and the pubis and just medial to the pulsating femoral artery. Twenty cc. of the 52½ per cent diodrast solution, which had been previously warmed in a water bath to bring it to body temperature, was drawn into a 20 cc. syringe. With the fingers of one hand palpating the femoral artery, a #18 needle attached to the syringe was inserted through the previously prepared skin into the femoral vein, which is located just medial to the artery. When a small amount of venous blood appeared in the syringe the diodrast was injected as rapidly as possible, approximately 2 cc. per second.

As the injection of 20 cc. was completed, the usual kidney-ureter-bladder exposure was made on a 14 by 17 film. After withdrawing the needle a moderate amount of pressure was employed locally over the point of venipuncture. A film thus obtained is demonstrated in Fig. 7. However, if a moderate amount of pressure is applied by "snugging down" the x-ray table compression band over a folded piece of toweling placed upon the central and upper abdomen, the return flow in the inferior vena cava is impeded and a very different venous pattern is obtained (Fig. 8).

Fig. 7 demonstrates the normal, unimpeded filling following the rapid injection of 20 cc. of diodrast solution into the right femoral vein. In Fig. 8 the abdominal compression has resulted in an occlusion of the inferior vena cava, and the extensive collateral circulation is demonstrated. The blood has been shunted into the large pelvic veins, the sacral veins are filled and both ascending lumbar veins can be seen, particularly on the right. Also on the right side portions of the vertebral venous complex are noted at the level of the 3rd and 4th lumbar vertebra. The renal calyces and ureters are partially outlined as a result of an injection done about 10 minutes earlier.

In another patient a similar injection into the right femoral vein with abdominal compression applied demonstrated a shunting into the ascending lumbar vein and vertebral veins on the right side (Fig. 9). On another occasion the same subject was injected as previously, abdominal compression applied and a film of the chest and dorsal spine was obtained (Fig. 10). Along the right border of the upper lumbar vertebrae the right ascending lumbar vein and its segmental connections with vertebral veins can be seen. As it is followed upward at the proximal portion of the 12th rib its connections with several of the intervertebral veins of the lower thoracic vertebrae are shown. This plexus of vessels unites to form the lower portion of the azygos vein, which can be seen ascending up to the mid-thoracic region parallel and just to the right of the spinous processes of the dorsal vertebrae.

FIG. 10. Showing continuity of the inferior portion of the azygos vein with the right ascending lumbar vein.

Upon four occasions the cephalic vein was injected into the anterolateral aspect of the upper arm. An example of normal filling is shown in Fig. 11. The right cephalic vein is shown arching downward into and filling the right axillary vein and the subclavian vein. The right innominate vein is

FIG. 11 (*left*). Twenty cc. of diodrast has been injected into cephalic vein in upper arm, with normal filling.

FIG. 12 (*right*). Twenty cc. of diodrast was injected into cephalic vein in upper arm while the subject attempted a forced expiration with glottis closed (Valsalva's Exp.).

partially outlined just to the right of the midline at the lower extent of the film. Crossing the cephalic vein a portion of the transverse scapular vein is demonstrated.

However, when a similar injection is done while the intrathoracic pressure is elevated very little diodrast passes beyond the subclavian vein, and it has "backed-up" into all of the transverse cervical, scapular and deep cervical veins (Fig. 12). Also portions of the left internal and external jugular veins and the vertebral venous system on the left side are shown.

## DISCUSSION

The vertebral venous system may be looked upon as a continuous chain of vessels extending from the pelvis to the cranial venous sinuses. The venous pattern obtained in these studies indicates that the ascending lumbar veins, the azygos venous system and the deep cervical venous plexuses can be considered as part of this system (Fig. 13). The venous pressure is relatively low in this system and the circulation is slow and subject to reversals of the direction of flow. The segmental connections at each interspace via the intervertebral veins with all of the adjacent axial structures of the neck, chest and abdomen are evident and an increase in intra-abdominal or intrathoracic

pressure results in an egress of venous blood into the vertebral veins. Hence emboli which have gained access to this venous complex can easily ascend or descend along the vertebral veins. Their direction and ultimate destination depend upon a variety of factors, such as posture and gravity, coughing or straining and the character of the circulation of allied systemic, portal and pulmonary systems.

The spread of bony metastases from carcinoma of the prostate has been found to parallel this vertebral venous pattern[1,5] and there is pathological

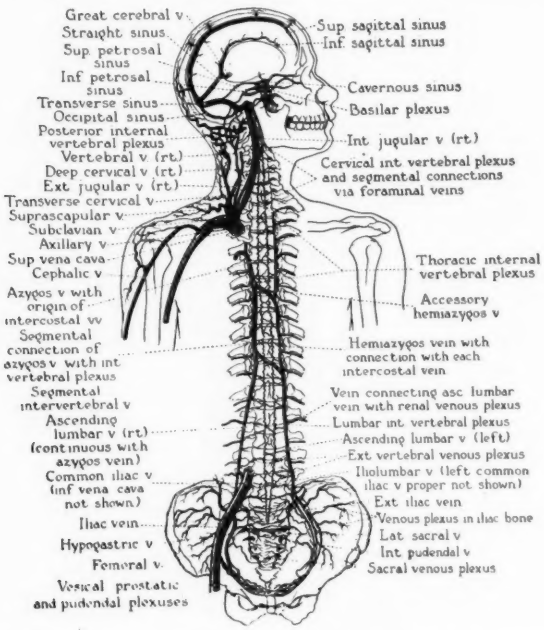
Great cerebral v.
Straight sinus
Sup. petrosal sinus
Inf. petrosal sinus
Transverse sinus
Occipital sinus
Posterior internal vertebral plexus
Vertebral v. (rt.)
Deep cervical v. (rt.)
Ext. jugular v. (rt.)
Transverse cervical v.
Suprascapular v.
Subclavian v.
Axillary v.
Sup. vena cava
Cephalic v.
Azygos v. with origin of intercostal vv.
Segmental connection of azygos v. with int. vertebral plexus
Segmental intervertebral v.
Ascending lumbar v. (rt.) (continuous with azygos vein)
Common iliac v. (inf. vena cava not shown)
Iliac vein
Hypogastric v.
Femoral v.
Vesical prostatic and pudendal plexuses
Sup. sagittal sinus
Inf. sagittal sinus
Cavernous sinus
Basilar plexus
Int. jugular v. (rt.)
Cervical int. vertebral plexus and segmental connections via foraminal veins
Thoracic internal vertebral plexus
Accessory hemiazygos v.
Hemiazygos vein with connection with each intercostal vein
Vein connecting asc. lumbar vein with renal venous plexus
Lumbar int. vertebral plexus
Ascending lumbar v. (left)
Ext. vertebral venous plexus
Iliolumbar v. (left common iliac v. proper not shown)
Ext. iliac vein
Venous plexus in iliac bone
Lat. sacral v.
Int. pudendal v.
Sacral venous plexus

FIG. 13. Composite, semidiagrammatic drawing of cerebral and vertebral venous systems, based on results of these experiments and standard anatomy texts. The left iliac vein and inferior vena cava were omitted so that the lumbar vertebral plexus could be illustrated more clearly.

and anatomical evidence that renal tumors may also metastasize by this route.[2,13] As previously mentioned, the vertebral venous system has been implicated as the mode of spread of cerebral metastatic abscess complicating suppurative thoracic disease.[7] The close relationship of the cerebral sinuses, the deep cervical veins and the vertebral veins with those of the shoulder girdle and of the breast may be an explanation for the frequency of cerebral and vertebral metastases complicating carcinoma of the thyroid and of the breast.[1]

Cases of superior sagittal sinus thrombosis complicating puerperal femoral and pelvic thrombosis, in the absence of cardiac or pulmonary path-

ology, have been described by Martin[14] in which the vertebral venous system was regarded as the only logical vehicle of spread. In a review of a group of cases of metastatic abscess complicating thoracic disease it was reported that the cerebral lesion was usually on the same side as the initial thoracic lesion and this was interpreted as evidence of the route of metastasis as being via the vertebral veins.[19] Ver Brugghen[20] presented clinical evidence of the vertebral venous system in the metastatic spread of tumors to the cerebrum.

Bailey has objected to Batson's theory of vertebral venous carcinomatous metastases to the brain because he believes that such growths are rarely found in the spinal canal and because intracranially the metastases are usually found as discrete nodules deep within the brain rather than in the venous sinuses and meninges.[4] In this series of 1076 verified tumors there were 72 cases of carcinomatous cerebral lesions and 15 intraspinal cases of metastatic carcinoma. This number is much less than the number of cerebral lesions but the relative bulk of the spinal cord and its meninges likewise is much less than that of the brain and therefore the chance of metastatic involvement is proportionately less, regardless of the mode of spread. Further, Willis has noted that it is the carcinomas of the lung and of the breast that are most frequently responsible for metastases to the spinal cord as well as to the brain.[22] As regards the depth of the cerebral metastatic lesions, they often occur at the junction of the cortical gray matter and the white matter, but the deeper structures, such as the basal ganglia, are also frequently the sites of growth.[18,22] In the retrograde venous filling of diodrast (Fig. 5) it is evident that the internal cerebral veins are filled as well as the external venous sinuses; in fact the internal cerebral veins and the great cerebral vein of Galen are particularly well demarcated. Therefore, according to these studies retrograde venous metastases could occur deep within the cerebrum as well as superficially.

These studies and the clinical correlation give additional credence to the part the vertebral venous system plays in the spread of metastases. It is realized that other factors, such as specific tissue susceptibility, chemical, hormonal and metabolic conditions[22] play a large part in the final success or failure of tumor emboli to grow in tissue to which they have been conveyed.

## CONCLUSIONS

1. The elementary, segmental character of the vertebral venous system and its continuity with the cerebral venous sinuses has been demonstrated roentgenologically by the employment of a 52½ per cent solution of diodrast (3,5-diiodo-pyridone-N-acetic acid and diethanolamine).

2. The close relationship of this venous system with the veins of other axial structures, such as the prostate, kidneys and adrenals, lungs, breast and thyroid, has been demonstrated.

3. The shunting of blood from the systemic circulation into the vertebral venous system has been demonstrated roentgenologically in living subjects.

4. These studies are considered further supportive evidence of possible

routes for spread of metastases via the vertebral venous system from distant primary foci to the cerebrum.

## REFERENCES


1. Ackerman, L. V., and del Regato, J. A. Cancer. Diagnosis, treatment, and prognosis. *St. Louis. C. V. Mosby*, 1947, 1115 pp.
2. Anson, B. J., Cauldwell, E. W., Pick, J. W., and Beaton, L. E. The blood supply of the kidney, suprarenal gland, and associated structures. *Surg. Gynec. Obstet.*, 1947, *84:* 313–320.
3. Anson, B. J., Cauldwell, E. W., Pick, J. W., and Beaton, L. E. The anatomy of the pararenal system of veins, with comments on the renal arteries. *J. Urol.*, 1948, *60:* 714–737.
4. Bailey, P. Intracranial tumors. *Springfield, Ill.: Charles C Thomas*, 1948, 2nd ed., xxiv, 478 pp.
5. Batson, O. V. The function of the vertebral veins and their rôle in the spread of metastases. *Ann. Surg.*, 1940, *112:* 138–149.
6. Batson, O. V. The rôle of the vertebral veins in metastatic processes. *Ann. intern. Med.*, 1942, *16:* 38–45.
7. Collis, J. L. The etiology of cerebral abscess as a complication of thoracic disease. *J. thorac. Surg.*, 1944, *13:* 445–470.
8. Courville, C. B. Pathology of the central nervous system. A study based upon a survey of lesions found in a series of thirty thousand autopsies. *Mountain View, Calif.: Pacific Press Publishing Association*, 1945, 2nd ed., 450 pp.
9. Cushing, H. Intracranial tumours. Notes upon a series of two thousand verified cases with surgical-mortality percentages pertaining thereto. *Springfield, Ill.: Charles C Thomas*, 1932, xii, 150 pp.
10. Fariñas, P. L. Abdominal venography. *Amer. J. Roentgenol.*, 1947, *58:* 599–602.
11. Fried, B. M., and Buckley, R. C. Primary carcinoma of the lungs. IV. Intracranial metastases. *Arch. Path.*, 1930, *9:* 483–527.
12. Harris, H. A. A note on the clinical anatomy of the veins, with special reference to the spinal veins. *Brain*, 1941, *64:* 291–300.
13. Herlihy, W. F. Revision of the venous system. The role of the vertebral veins. *Med. J. Aust.*, 1947, *1:* 661–672.
14. Martin, J. P. Thrombosis in the superior longitudinal sinus following childbirth. *Brit. med. J.*, 1941, *2:* 537–540.
15. Morris, H. Morris' human anatomy. A complete systematic treatise. C. M. Jackson, Ed. *Philadelphia: P. Blakiston's Son & Co., Inc.*, 1933, 9th ed., xiv, 1481 pp.
16. O'Loughlin, B. J. Roentgen visualization of the inferior vena cava. *Amer. J. Roentgenol.*, 1947, *58:* 617–619.
17. v. Recklinghausen, F. Ueber die venöse Embolie und den retrograden Transport in den Venen und in den Lymphgefässen. *Virchows Arch.*, 1885, *100:* 503–539.
18. Rich, G. J. The distribution of metastatic tumors in the cerebrum. *Arch. Neurol. Psychiat., Chicago*, 1930, *23:* 742–749.
19. Rizzoli, H. V., McCune, W. S., and Sherman, I. J. Surgical management of metastatic brain abscess. *J. Neurosurg.*, 1948, *5:* 372–384.
20. Ver Brugghen, A. Cerebral metastasis. Presented at meeting of Chicago Surgical Society, Nov. 4, 1949.
21. Wechsler, I. S., and Kaplan, A. Cerebral abscess (paradoxic) accompanying congenital heart disease. Report of two cases. *Arch. intern. Med.*, 1940, *66:* 1282–1289.
22. Willis, R. A. The spread of tumours in the human body. *London: J. & A. Churchill*, 1934, x, 340 pp.

# EXPERIMENTAL STUDIES OF THE EFFECT OF COAGULATING CURRENTS* UPON THE BRAIN

## WHEN APPLIED TO THE INTACT DURA AND DIRECTLY ON THE CORTEX

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A FUNDAMENTAL problem in surgery of the nervous system is the control of bleeding, and a basic method of hemostasis in neurosurgery is the coagulating current of the surgical diathermy. Diathermy machines for medical and surgical use are based on the observation of d'Arsonval[1] that alternating currents ceased to stimulate at very high frequencies and that the only apparent effect was the production of heat. By variations in character and manner of application, three tissue effects, which have surgical applications, are produced by diathermy currents: coagulation, cutting and desiccation.

The first surgical diathermy was constructed by Doyen[10] and utilized the original circuit of d'Arsonval; it generated a very damped, high frequency current. Such a current produces a coagulation necrosis of tissue with complete cellular disruption to a depth dependent on the strength of current and duration of flow. It effects hemostasis by shrinkage of blood vessels and formation of an occluding coagulation.

Clark[5] originated the technique of electrodesiccation, which is produced by placing the active electrode at such a distance from the tissue that sparks pass across the gap. This causes a superficial layer of dehydrated tissue; the effect seems to be a lesser degree of the coagulation process.

The cutting effect is produced by an undamped, high frequency current; it was first perfected by Wyeth.[21] With this current, the tissues separate before the electrode, producing an actual incision and little or no hemostasis.

Bovie[8] devised a surgical diathermy in which the cutting and coagulating currents could be combined and incisions could be made with adequate control of hemorrhage. This was the instrument used by Cushing[7] when he, in 1927, introduced "electro-surgery" into neurosurgery as an adjunct in the removal of the more inaccessible meningiomas. This machine was accepted as a basic advance in neurosurgery, and its use was quickly extended into all phases of neurosurgery with an emphasis on the hemostatic effect of the coagulating current.

* Supported in part by grants from the National Cancer Institute, U.S.P.H., and the Atomic Energy Commission.

† Grafton A. Smith—Senior Fellowship, U.S.P.H.

It soon became apparent that use on the skin of even the cutting current was inconsistent with primary healing,[6,12,13,15,16] but little reference to its harmful effects on nervous tissue is to be found.

Moore and associates[17] demonstrated in this clinic that abnormal areas of nervous tissue (especially tumors) are usually stained by the dye fluorescein in contradistinction to the normal brain tissue, which is not stained. The identification of abnormal tissue was proved to be so reliable with the fluorescein technique that it is used routinely when the possibility exists of encountering tumor or abscess at craniotomy. Subsequently, it was noted by one of us (L.A.F.) that the dye had stained a small area of cortex underlying a site of dural coagulation. This observation has been confirmed in subsequent craniotomies.

The present report deals with the results of animal investigations into the characteristics of changes produced in the brain by the coagulating current as demonstrated by the fluorescein technique.[17]

## METHODS AND MATERIALS

The animals used were mongrel dogs and stock rabbits. Under sodium pentobarbital anesthesia, the dura over the cerebral hemispheres was exposed through a trephine opening or more extensive craniectomy. Every effort was made to maintain the integrity of the dura and to prevent trauma to the underlying cortex. In acute experiments the surgery was done merely under "clean" conditions; otherwise, strict operating room aseptic technique was maintained.

Coagulation current was applied with the ball point electrode of a spark-gap, surgical diathermy.* The inactive, plate electrode was placed on the shaved hind limb with saline to insure an efficient contact. At times a radio-frequency ammeter was placed directly in the circuit of the active electrode and readings were taken during coagulation.

In most animals the electrode was gently applied to the intact dura. Coagulations were done for measured time intervals at varying dial settings. In studies to determine the appearance time of the fluorescence it was necessary to reflect a dural flap and coagulate the cortex directly. Control animals underwent the same procedure except that the current was not turned on.

Examination of the coagulated areas was carried out under ultraviolet light,† after the injection of fluorescein. All studies of the appearance time and ancillary examinations were done on living animals. For the remaining studies, the animals were sacrificed by cardiosection after injection of the dye; then, the brain was removed as a whole and examined.

Pathological sections were taken of representative areas and prepared with hematoxylin and eosin, Weil, and Nissl stains.

## RESULTS OF COAGULATION STUDIES

Preliminary studies were done to determine the influence of the current level (as determined by dial settings), and the time interval of application

* Manufactured by Liebel-Flarsheim Company, Cincinnati. (Improved Davis-Bovie machine.)
† CH-4 mercury vapor lamp with Wood's filter.

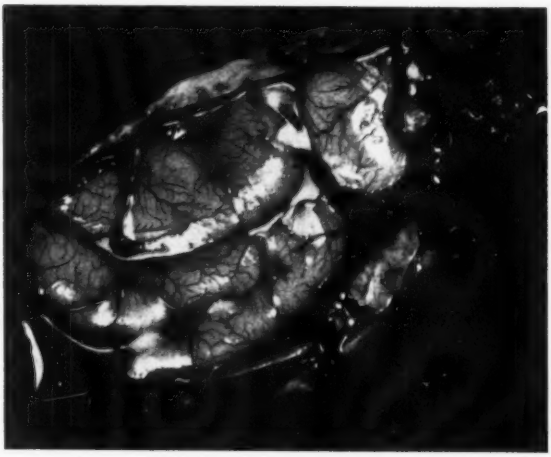

FIG. 1. Appearance of cerebral cortex (dog) underlying dura which had been subjected to a coagulating current (20 Bovie units) for 1, 3, and 5 seconds. There is no visible evidence of tissue damage except the area coagulated for 5 seconds (lower center).

FIG. 2. The same area exposed to ultraviolet light, 10 minutes after coagulation of the dura and the intravenous injection of sodium fluorescein (10 cc. 5 per cent sol.).

Topmost fluorescent area was coagulated for 1 second; the dura to the left, 3 seconds; and the large area in the lower center, 5 seconds. Note the slight fluorescence of the dural flaps.

of the electrode upon the production of fluorescent areas in the underlying cortex.

The following results were obtained:

1. With a dial setting of the Davis-Bovie machine below 10 units, fluorescence was never observed even though the application time was extended to 30 seconds.
2. There was an inconsistent production of fluorescence with dial settings between 10 and 15 units. However, fluorescence was more frequently observed with longer time intervals (15–30 seconds) and/or higher dial settings.
3. Above 15 units fluorescence of the cortex was invariably produced when the electrode was in contact with the dura for 1 second or more.
4. Below 25 units no gross or microscopic alterations of the cortex were evident.

On the basis of the above data a standard setting (20 u.) and a coagulation time interval (2 sec.) were chosen for further studies of appearance time and duration of cortical fluorescence.

Figs. 1 and 2 depict the appearance of the cortex under ordinary illumination and under ultraviolet light following application to the dura of a coagulating current (20 Bovie u.) for 1, 3, and 5 sec. intervals.

The dog was injected with sodium fluorescein and the photographs were taken after a 10 min. interval.

### APPEARANCE TIME OF FLUORESCENCE

Observations of deliberately produced coagulation spots in the human cortex revealed that fluorescence could be detected in the cortex 4–5 min. after dural coagulation, but did not reach a maximum until 8–12 min.

Table 1 shows the results of appearance studies done in animals.

TABLE 1

*The appearance time of fluorescence under coagulated areas*

| Animal | Contact Point | Unit Setting | Time of Application | Fluorescence Present |
|---|---|---|---|---|
| 1. Rabbit | Dura | 20 u. | 2 sec. | 8 min. |
| 2. Rabbit | Dura | 20 u. | 2 sec. | 5 min. |
| 3. Rabbit | Dura | 20 u. | 2 sec. | 5 min. |
| 4. Dog | Dura | 20 u. | 2 sec. | 4½ min.—vague |
| 5. Dog | Dura | 20 u. | 2 sec. | 7 min.—max. |
| 6. Rabbit | Brain | 20 u. | 2 sec. | 1 min.—20 sec. |
| 7. Rabbit | Brain | 20 u. | 2 sec. | 2 min. |
| 8. Rabbit | Brain | 20 u. | 2 sec. | 1 min.—45 sec. |

The areas produced by a standard (20 u./2 sec.) coagulation through the dura and those directly on the brain tissue were different in appearance time and general characteristics (Tables 2 and 3).

In animals with coagulation through the dura fluorescence appearance time was 4–5 min. and the maximal intensity was reached at 7½ min. Direct

TABLE 2

*Coagulation through dura (20 u./2 sec.)*

| Duration Interval before Observation | Size of Fluorescent Area | Description |
|---|---|---|
| 1 min. | 0 | 0 |
| 5 min. | 1.5 mm. | Vague, directly including area coagulated; solid coloration |
| 7½ min. | 4 mm. | Max. intensity; solid coloration |
| 10 min. | 4 mm. | Same |
| 15 min. | 4 min. | Same |
| 25 min. | 4 mm. | Same |

measurements revealed the lesions to average 5 mm. in diameter and extend to a depth of 0.5 to 1 mm.

In animals with direct coagulation of the cortex, appearance of fluorescence was from 1 min., 20 sec.–2 min., and the maximum intensity was attained between 22–25 min. The maximum extent of the lesion was 8 mm. in diameter and a depth of 2–2.5 mm.

In one instance it was observed that there was a narrow fluorescent band along one of the larger cortical blood vessels of an animal used for direct

TABLE 3

*Coagulation directly on cortex (20 u./2 sec.)*

| Duration | Size of Fluorescent Area | Description |
|---|---|---|
| 1.20 min. | 2.5 mm. | Faint fluorescent ring about non-fluorescent central area of coagulation |
| 5 min. | 5 mm. | Ring in outer diameter, with central area not fluorescent |
| 10 min. | 6 mm. | Same with slight fluorescent central area |
| 15 min. | 8 mm. | Increased fluorescence of central area |
| 24 min. | 8 mm. | Uniformly stained |

coagulation of brain tissue. This extended 6–7 mm. along the vessel from the area of coagulation. It appeared that the current had "traveled" along the vessel for some distance and produced a more distant injury than would usually be expected. This is in accordance with the clinical experience of one of us (L.A.F.).

It was also found that when coagulation was performed more than 35 min. after administration of fluorescein, there was little fluorescence. If another dose of 5 per cent fluorescein was given fluorescence of the lesion appeared immediately. This would be expected since it is known that the blood level of fluorescein after 30 min. is low.

DURATION OF FLUORESCENCE IN CORTICAL AREAS TRAUMATIZED BY ELECTROCOAGULATION

The animals were all operated upon under aseptic conditions, and the dura was coagulated in one or more areas through a 12 mm. trephine opening (Table 4). Sodium fluorescein was given 15 min. prior to cardiosection of the animal and the brain removed.

The persistent cortical lesions observed were recorded as present only when there was a definite area of fluorescence underlying the area of the

TABLE 4

*Experimental coagulation of the dura*

| Animal | Area No. | Bovie Unit Setting | Duration of Application (seconds) | Fluorescence | |
|---|---|---|---|---|---|
| | | | | Present | Absent |
| A Dog 1 | 1 | 30 u. | 5 | 6 hr. | |
| | 2 | 30 u. | 2 | 6 hr. | |
| | 3 | 30 u. | 1 | 6 hr. | |
| A Dog 2 | 1 | 40 u. | 5 | 6 hr. | |
| | 2 | 40 u. | 3 | 6 hr. | |
| A Dog 3 | 1 | 20 u. | 3 | 5 hr. | |
| | 2 | 20 u. | 3 | 6 hr. | |
| | 3 | 20 u. | 3 | 7 hr. | |
| | 4 | 20 u. | 3 | 8 hr. | |
| A Dog 4 | 1 | 20 u. | 3 | 12 hr. | |
| | 2 | 20 u. | 3 | 24 hr. | |
| | 3 | 20 u. | 3 | 36 hr. | |
| B Dog 5 | 1 | 20 u. | 3 | 48 hr. | |
| | 2 | 20 u. | 5 | 48 hr. | |
| B Dog 6 | 1 | 20 u. | 3 | 76 hr. | |
| | 2 | 20 u. | 5 | 76 hr. | |
| B Dog 7 | 1 | 20 u. | 3 | | |
| | 2 | 20 u. | 3 | | 2 mo. |
| Rabbit 2 | | 20 u. | 2 | 40 min. | |
| Rabbit 3 and 4 | | 20 u. | 2 | 6 hr. | |
| Rabbit 5 and 6 | | 20 u. | 2 | 7 and 8 hr. | |
| Rabbit 7 | | 20 u. | 2 | 24 hr. | |
| Rabbit 8 | | 20 u. | 2 | 48 hr. | |
| Rabbit 9 and 10 | | 20 u. | 2 | 48 hr. | |
| Rabbit 11 and 12 | | 20 u. | 2 | 52 hr. | |
| Rabbit 13 | | 20 u. | 2 | 72 hr. | |
| Rabbit 14 and 15 | | 20 u. | 2 | 7 d. | |
| Rabbit 16 and 17 | | 20 u. | 2 | 10 d. | |
| Rabbit 18 | | 20 u. | 2 | 14 d. | |
| Rabbit 19–22 | | 20 u. | 2 | | 14 d. |
| Rabbit 23–30 | | 20 u. | 2 | | 19–90 d. |

dura that was coagulated. If there was any herniation of cerebral cortex through the dural opening the animal was discarded, since it was demonstrated that herniation alone produced fluorescence. This confirms Broman's observation[3] that herniation impaired the blood-brain-barrier (BBB) of the affected cortex.

The duration of the break in the BBB persisted 10–14 days. The one case in which there was no fluorescence at the end of 48 hours is exceptional and the reason for this is not clear. Possibly the inactive electrode was not in good contact with the animal's leg and comparable degree of coagulation was not obtained.

The examination of control areas of 9 rabbits sacrificed in groups of 3 at 5, 10, and 19 days revealed no fluorescence.

## PATHOLOGY

No gross change in the dura or cortex (when visualized) could be seen after coagulation for 2 sec. with a 20 u. dial setting. An increase in the time interval at this setting to as much as 10 sec. produced no change. However, an increase in the unit setting with the time kept constant (2 sec.) produced progressively more distinct changes. At 25–30 u. a definite blanching and shrinkage of the tissue could be seen immediately; between 35 and 40 u. actual charring of the tissue occurred.

A limited number of animals were sacrificed at intervals of 1 day to 3 months after coagulation.

No remote gross alterations of the cortex were seen unless the coagulation had been severe enough to cause immediate evident injury, such as blanching or charring of the dura. Filmy meningeal adhesions were the most constant pathological finding, and the severity of these adhesions was proportional to the extent of the original injury. Examination also revealed round, punched-out areas of the cortex, which were about 1 mm. in depth, in those animals exposed to extensive coagulation. A few thrombosed blood vessels were also evident in the affected area.

Microscopic sections of the brain removed 1 week after the animal was exposed to a heavy dose of coagulation, showed the formation of a homogeneous necrotic mass in the center of the area of cortical reaction. Surrounding this area was a band of cerebral tissue containing many pyknotic and disrupted nuclei and extravasated erythrocytes. In general the severity of cellular damage was inversely proportional to the distance from the reaction center. In the farthest areas, only a slight invasion of round cells was seen. The only other striking finding was the presence of numerous thrombosed vessels near the reaction center.

After a few weeks there was no further evidence of necrotic tissue, but only a clean-cut, round depression with an absence of cortex; to this depression many fibrin bands were adherent. In the tissue surrounding the defect numerous large astrocytic cells and a few pyknotic nuclei were evident.

In contrast to findings outlined in the preceding paragraphs was the lack of pathology revealed in those animals subjected to the standard coagulation (20 u./2 sec.). It must be emphasized that in these animals no evidence of gross damage was seen immediately following coagulation. In these animals coagulated with 20 u. for 2 sec., repeated examination of the coagulated site, after injecting fluorescein intravenously, revealed fluorescence of the area as long as 14 days after the original injury, but no fluorescence of the coagulation site was noted in animals examined at 3, 4, 6, 8, and 12 weeks. Careful microscopic examination of multiple sections stained with hematoxylin and eosin, Weil, and Nissl techniques failed to reveal any cytological abnormalities of the underlying cortex.

### ATTEMPTS TO MEASURE THE CURRENT FLOW

A shunted radio-frequency ammeter with a rate of 0–250 mA. was placed directly in the circuit of the active electrode in an effort to accurately measure the current flow of each coagulation. This was done because it was thought that differences in contact, resistance, and other variables might cause significant changes in current flow even though contact time and the dial settings were constant.

Trials immediately demonstrated that absolute readings could not be made as the readings of the ammeter at low dial settings were greater when current was allowed to flow with no conduction between active and inactive electrodes than when the animal was coagulated, but with dial settings above the range of 8–10 u. the ammeter readings were greater when tissue was coagulated.

It was determined that a constant relationship for any one preparation could be established by subtracting the "off" values (the reading with no conducting tissue between the electrodes) from the "on" values (the readings when the tissues were coagulated). A negative value was recorded when "off" was greater than "on."

A series of coagulations were made, at different dial settings, on a rabbit (2 kg. in weight). This was followed by a parallel experiment with a dog (25 kg.) in order to detect differences arising from the differences in body mass. There was no significant difference in the values obtained. This was interpreted as indicating that the size of the animal had no influence on the measurable amount of current flowing.

## DISCUSSION

Fluorescein is an acid chromogen dye which is light yellow in dilute solutions at physiological pH ranges. Because of its property of brilliant greenish-yellow fluorescence under ultraviolet light, it can be detected when present in minute quantities. In common with other negatively charged ions, it does not pass readily from the blood into normal central nervous tissue or cerebrospinal fluid when given in non-toxic doses—i.e. it can be used to demonstrate the so-called blood-brain-barrier phenomenon. The precise mech-

anism and localization of the BBB is disputed but the most accepted theory maintains that it is a specific permeability property of the central nervous system vessels.[3]

The failure of acid dyes to pass the BBB into normal nervous tissue has been well enough documented to conclude that a definite abnormality in the barrier is present when such passage is demonstrated.[3]

The use of the fluorescein test in routine neurosurgical procedures at this hospital has led to confidence in its ability to demonstrate abnormal tissue. There have been very few false positive interpretations in $3\frac{1}{2}$ years of experience.

Because of a clinical impression that patients who had undergone direct coagulation of the brain did not have as smooth a postoperative course, hemostasis by coagulation in this clinic has been reserved for extraneural tissue. Therefore when a very fluorescent area in the cortex was found to result from coagulation of the dura, the observation was felt to be of importance.

It is apparently common knowledge in neurosurgery that the spinal cord and brain stem should not be coagulated, but an extensive review of electrosurgical literature revealed no reports of ill effects from such a procedure. There are warnings against it in standard neurosurgical texts but no supporting data or references are given.[2,18]

Reports on the use of the surgical diathermy in neurosurgery have given little consideration to the question of harmful effects from the use of diathermy on nervous tissue. Cushing[7] in reporting its initial use gave no direct discussion of the problem. In one of his case reports there is mention of convulsions coincident with coagulation of the dura. These, however, may well have resulted from stimulation of secondary faradic currents whose presence in the early surgical units have been reported.[12]

Davis and Groen[9] saw no change in the postoperative courses of patients that they ascribed to undesirable effects of electrosurgery.

Sachs[19] gave the opinion that any possible damage was no more than that produced by other means of hemostasis.

Broman[3] has recently published a monograph on the blood-brain-barrier in which the literature and his extensive personal investigations, utilizing the dye trypan blue as an indicator, are summarized. His observations prove the barrier to be amazingly resistant to change; it even persists for several hours after death. He reported several methods that produced a transient and inconstant breakdown of the barrier; these included microembolism, allergic reactions, intracarotid injections of contrast media, insulin reaction and metrazol toxicity. Only with solid emboli were changes lasting over a few hours produced; a maximum of 5 days was recorded. It is entirely possible that the precipitating cause in this instance (the emboli) continued to act over the entire period of time.

After this study was begun, a report by Broman and associates,[4] concerned with the effect of electrocoagulation on the BBB, became available.

These investigators found that coagulation consistently made the BBB permeable to trypan blue for a duration of 7–11 days. Three possible theories to explain this effect were presented:

1. There is a specific characteristic of the damage due to electrocoagulation.
2. There is a toxic effect produced by necrotic tissue (apparently Broman *et al.* always produced necrosis in their experiments).
3. There is an ingrowth of new capillaries which do not immediately "develop" the barrier phenomenon.

The present studies show that the alteration in the barrier must be the result of a specific property of electrocoagulation or, more likely, the heat it produces, because necrotic tissue was absent (gross and microscopic studies) at intensities of coagulation that consistently "broke" the barrier. In these same sections, there were no changes in the blood vessels, much less the growth of new capillaries.

That these changes were due to infection is very unlikely, since microscopic preparations revealed none of the changes usually accompanying infection.

If these changes in the barrier were perpetuated by substances present in the circulation, the same factors should have been in operation to prolong the very transient "breaks" produced by other means than solid emboli and electrocoagulation.

The extreme sensitivity of the fluorescein technique is revealed by the absence of any change to be seen under the microscope. The maximum duration (14 days) given by fluorescein was somewhat longer than the maximum given by the trypan blue technique. This may indicate that the fluorescein test is more sensitive, especially since it appears that Broman used a higher intensity of coagulation. However, it should be noted that Broman used a different experimental animal (cat) and therefore the experiments cannot be compared directly.

The importance of the findings in this study are emphasized by the relative indestructiveness of the brain as demonstrated by Broman and others.[3] Furthermore, the changes produced are not limited to the surface but in some instances extended to the ventricular wall.

The failure to make an absolute measurement of the current with a R-F ammeter is not surprising in light of the similar experience of Hemingway[14] in attempts to measure the dosage of medical diathermy.

The pathological changes seen in microscopic sections resemble closely those reported by Silver and Walker[20] and Dusser de Barenne and Zimmerman[11] to be produced by simple heat.

## CONCLUSIONS

1. A profound alteration in the permeability of the cerebral vessels as demonstrated by fluorescein is produced by the passage of a coagulating current of such low strength that neither gross nor microscopic changes can

be detected. Disruption of the blood-brain-barrier occurs even when the dura is the primary site of coagulation.

2. This alteration does not result from the toxic products of necrosis or from the formation of new vessels. It is probably the result of heat but in addition there may be changes caused by a specific effect of the coagulating current.

3. In view of the production of such sustained alteration in the BBB, the coagulating current should be used sparingly on the central nervous system, and probably not at all in vital areas.

4. The use of a shunted radio-frequency ammeter to measure absolute current flow in electrocoagulation did not prove practical.

5. The lesions produced by higher intensities of coagulating current could be seen upon microscopic study and resembled those produced by simple heat.

## REFERENCES


1. D'Arsonval, A. Action physiologique des courants alternatifs à grande fréquence. *Arch. Physiol. norm. path.*, 1893, 5s. *5:* 401–408.
2. Bailey, P. Intracranial tumors. *Springfield, Ill.: Charles C Thomas*, 1948, 2nd ed., xxiv, 478 pp.
3. Broman, T. The permeability of the cerebrospinal vessels in normal and pathological conditions. *Copenhagen: E. Munksgaard*, 1949, 92 pp.
4. Broman, T., Radner, S., and Svanberg, L. The duration of experimental disturbances in the cerebrovascular permeability due to circumscribed gross damage of the brain. *Acta psychiat., Kbh.*, 1949, *24:* 167–173.
5. Clark, W. L. Oscillatory desiccation in the treatment of accessible malignant growths and minor surgical conditions. A new electrical effect. *J. adv. Ther.*, 1911, *29:* 169–180.
6. Crowell, B. C. Report on research on electrosurgery. *Surg. Gynec. Obstet.*, 1931, *52:* 521.
7. Cushing, H. The meningiomas arising from the olfactory groove and their removal by the aid of electro-surgery. *Lancet*, 1927, *1:* 1329–1339.
8. Cushing, H., and Bovie, W. T. Electro-surgery as an aid to the removal of intracranial tumors. With a preliminary note on a new surgical-current generator. *Surg. Gynec. Obstet.*, 1928, *47:* 751–784.
9. Davis, L., and Groen, B. M. Use of electrosurgery in neurological surgery. *Amer. J. Surg.*, 1930, n.s. *9:* 207–217.
10. Doyen, E. Sur la destruction des tumeurs cancéreuses accessibles par la méthode de la voltaïsation bipolaire et de l'électro-coagulation thermique. *Arch. Élect. méd.*, 1909, *17:* 791–795.
11. Dusser de Barenne, J. G., and Zimmerman, H. M. Changes in the cerebral cortex produced by thermocoagulation. A suggestion to neurosurgery. *Arch. Neurol. Psychiat., Chicago*, 1935, *33:* 123–131.
12. Ellis, J. D. Electrosurgical incisions. Histologic effects. *Arch. Surg., Chicago*, 1933, *26:* 981–998.
13. Gottesman, J., Perla, D., and Ziegler, J. M. The effects of the electrocautery on normal tissues. *Surg. Gynec. Obstet.*, 1930, *51:* 667–673.
14. Hemingway, A. Physical and biological aspects of short wave diathermy. *Arch. phys. Ther.*, 1939, *20:* 24–28.
15. Kelly, H. A. Electrosurgery. *Surg. Gynec. Obstet.*, 1931, *52:* 502–504.
16. McLean, A. J. The Bovie electrosurgical current generator. Some underlying principles and results. *Arch. Surg., Chicago*, 1929, *18:* 1863–1873.
17. Moore, G. E., Peyton, W. T., French, L. A., and Walker, W. W. The clinical use of fluorescein in neurosurgery. The localization of brain tumors. *J. Neurosurg.*, 1948, *5:* 392–398.
18. Pilcher, C. General principles of neurosurgical technic. In: *Surgical treatment of the nervous system.* F. W. Bancroft and C. Pilcher, Ed., Philadelphia: J. B. Lippincott, 1946, xvii, 534 pp. (see pp. 3–15).
19. Sachs, E. Electrosurgical unit as an aid to the neurologic surgeon. *Surg. Gynec. Obstet.*, 1931, *52:* 505–507.
20. Silver, M. L., and Walker, A. E. Histopathology of thermocoagulation of the cerebral cortex. *J. Neuropath. exp. Neurol.*, 1947, *6:* 311–322.
21. Wyeth, G. A. The endotherm. *Amer. J. Electrother.*, 1924, *42:* 186–187.

# AN EXPERIMENTAL METHOD FOR THE EVALUATION OF CONTRAST MEDIA USED IN CEREBRAL ANGIOGRAPHY

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CONTRAST media used for cerebral angiography must not only visualize the cerebral vascular tree in an adequate manner but must also be relatively non-toxic in volumes and concentrations necessary for their primary purpose. Several clinical studies have noted immediate untoward effects following the injection of Diodrast, emphasizing chiefly subjective head pain and rare sensitivity reactions.[6,7,9,10,13,14] Pathological changes secondary to the injection of Thorotrast have been reported.[5,12] One experimental study has concerned itself with histopathologic changes following the use of Perabrodil (Diodrast).[11] Neither the clinical nor the histopathological studies have furnished sufficient information to deter the use of these substances.

Broman, on the other hand, using the physiological approach of injecting the dye trypan blue with Diodrast-like substances, has demonstrated unequivocal changes in the permeability of the vessels.[2,3,4] He attributes these changes to a chemo-toxic influence upon the endothelium of the vessel wall. While this report was in preparation, Broman reported further studies along this same line.[1] It is desirable to objectively evaluate the effect of any contrast medium upon the function as well as structure of the brain. The present method of study combines the dye indicator technique with concomitant electroencephalography in an effort to obtain evidence of more subtle changes in cerebral physiology as well as correlative data.

## EXPERIMENTAL METHOD

Adult rabbits were used in this study, since, of all common laboratory animals, they alone receive a significant volume of blood to the cerebral hemisphere through the internal carotid artery. Friedemann[8] has shown that anionic dyes permeate damaged vascular endothelium while sparing unaltered blood vessels. The tetra-sulfonic acid of copper phthalo-cyanine (tetra-sulfon-tetra-benzo-tetra-azo-porphin) is such an anionic dye, and other work in this laboratory has revealed that it fulfills these requirements.

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This dye is readily soluble in Ringer's solution, yielding a brilliant blue solution when prepared for injection.

Under light nembutal and local procaine anesthesia, the right or left internal carotid artery of alternate animals was isolated in the neck. A small polyethylene catheter was inserted into the common carotid artery proximal to the ostium of the internal carotid. Tracheotomy was then done; the animal was curarized and placed upon mechanical respiration.

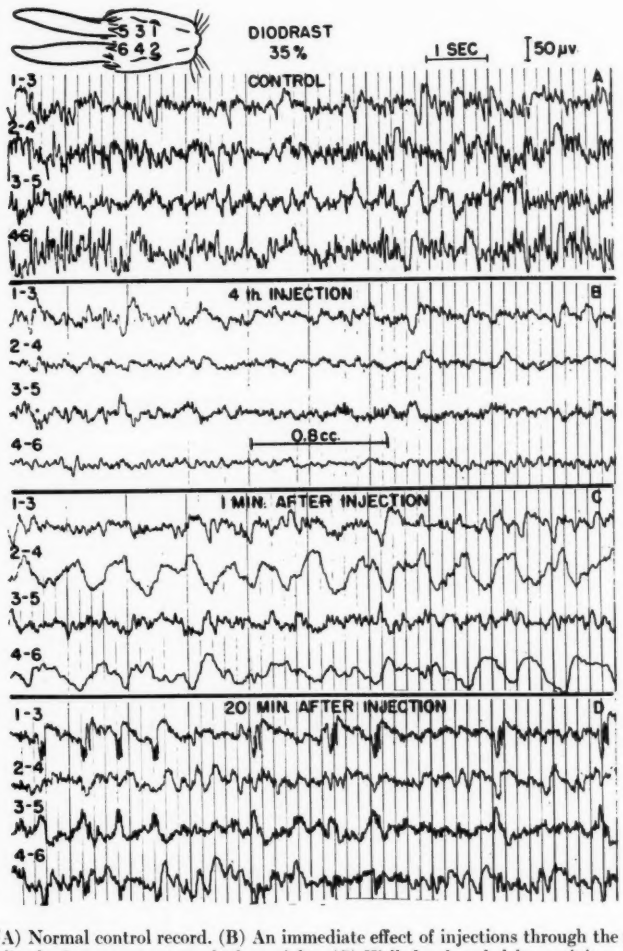


FIG. I. (A) Normal control record. (B) An immediate effect of injections through the right internal carotid; amplitude decrease most marked on right. (C) Well developed delta activity over the right hemisphere 1 min. after injections. (D) Seizure discharges occurring 20 min. after injections. Last two channels of the record have been deleted.

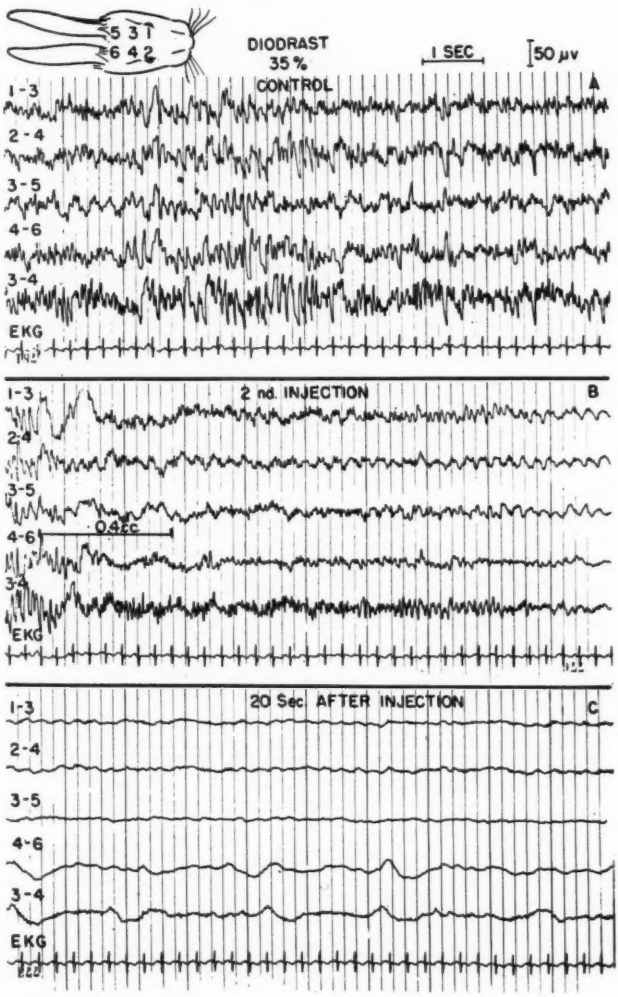


FIG. 2. (A) Normal control record. (B) An immediate amplitude decrease, and appearance of generalized slow activity. (C) Example of generalized disappearance of cortical activity following the 2nd injection of the test substance.

The test substance was injected, as a rule, in four increments 10 sec. apart in order to allow circulation of blood between injections. The usual injection time was 2 to 3 sec. for a volume of 0.4 cc. and larger amounts required correspondingly longer times. All test injections were controlled with similar amounts of Ringer's solution. The dye indicator was subsequently administered in the course of the acute experiment in 80 to 100 mg. amounts either intravenously or through the

internal carotid artery. In positive experiments, more intense staining was noted when the dye was injected by the carotid route. The dye was allowed to circulate at least 45 min. before completion of the experiment. Each preparation was checked for filling of the internal carotid by the removal of the brain and the injection of fluid through the catheter.

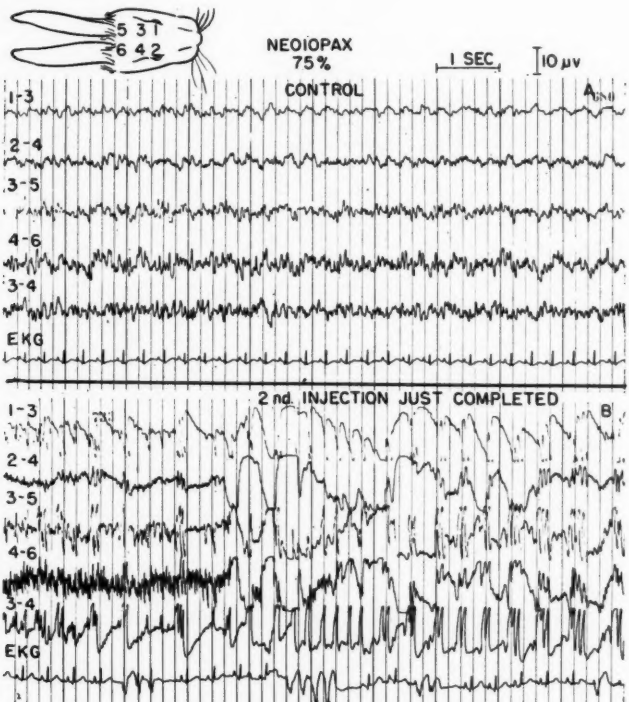


FIG. 3. (A) Normal control record. (B) Example of seizure discharges immediately after the 2nd injection of the test substance. Note the EKG changes.

All EEGs (Figs. 1, 2 and 3) were obtained on a standard 6 channel Grass electroencephalograph, using 6 needle electrodes inserted symmetrically in the scalp. Records were obtained continually with bipolar leads during the study period. So that EEG changes could be tabulated, the following classification was established:

0 = No change.
1+ = An amplitude decrease with diminished secondary activity or transient delta activity lasting less than 5 min.
2+ = A well developed delta focus and/or generalized slow activity lasting 5 to 10 min.
3+ = A delta focus and/or generalized slow activity lasting more than 10 min.
4+ = Severe depression of all cortical activity persisting up to 1 hr.

TABLE 1

| Media | Total Dose | EEG Change | Ipsilateral Staining |
|---|---|---|---|
| R O 70% | 3.2 cc. | 4+ | yes |
| R O 70% | 3.2 cc. | 4+ | yes |
| R O 70% | 1.6 cc. | 4+ F | yes |
| R O 70% | 0.4 cc. | 4+ | yes |
| Urokon 30% | 1.6 cc. | 4+ | no |
| Diodrast 70% | 0.8 cc. | 4+ F | yes |
| Neoiopax 75% | 4.8 cc. | 4+ G | yes |
| Neoiopax 75% | 4.8 cc. | 4+ G | yes |
| Neoiopax 75% | 2.4 cc. | 4+ G | yes |
| Neoiopax 75% | 0.8 cc. | 4+ G | yes |
| Diodrast 35% | 4.8 cc. | 3+ G | yes |
| Diodrast 35% | 3.2 cc. | 3+ F | no |
| Diodrast 35% | 1.6 cc. | 3+ F | no |
| Diodrast 35% | 0.8 cc. | 3+ F | no |
| Diodrast 70% | 1.6 cc. | 3+ F | no |
| Neoiopax 75% | 1.6 cc. | 3+ F | no |

F = Focal electrical seizure. G = Generalized electrical seizure.

## RESULTS

At this time, 29 observations have been made on 24 animals, using as test substances Thorotrast, 35 per cent Diodrast, 70 per cent Diodrast, 75 per cent Neoiopax, and 30 per cent Urokon, all commercially available contrast substances. In addition, 2, 4 dioxo-3 iodo, 6 methyl-tetra-hydropyridine-N-acetic acid in 70 per cent solution (RO), an experimental medium, has been used (Hoffmann-La Roche, Inc.).

The results secured in the preliminary application of this method of contrast media study are tabulated (Tables 1 and 2). The correlation between dye staining and EEG changes shows that 9 of 10 animals with 4+ EEG changes showed brain staining, an indication of altered vascular permeability. Only 1 of 6 animals with 3+ changes showed brain staining. Vital staining was never observed in animals with 1+ and 2+ EEG alterations. No statistical correlation is possible between the incidence of seizures and tissue staining.

TABLE 2

| Media | Total Dose | EEG Change | Ipsilateral Staining |
|---|---|---|---|
| Thorotrast | 4.8 cc. | 2+ | no |
| Urokon 30% | 3.2 cc. | 2+ F | no |
| Urokon 30% | 1.6 cc. | 2+ | no |
| Urokon 30% | 1.6 cc. | 2+ | no |
| Diodrast 35% | 1.6 cc. | 2+ | — |
| Neoiopax 75% | 1.6 cc. | 2+ | — |
| Thorotrast | 1.6 cc. | 1+ | no |
| Thorotrast | 3.0 cc. | 1+ | no |
| Thorotrast | 3.0 cc. | 1+ | no |

## DISCUSSION

From these results it appears that the combined method of indicator dye injection and electroencephalography will serve as a useful technique for the objective evaluation of contrast media used or proposed for cerebral angiography. The contrast media tested appear capable of altering both cerebral vascular permeability and cerebral electroactivity when injected within the cerebral circulation in the dosages indicated. Studies now in progress will enlarge the statistical import of these findings in terms of separate media and will include histopathological preparations of the stained brain parenchyma.

The authors wish to thank Dr. Barnes Woodhall for his assistance in the conduct of this investigation and the preparation of the manuscript.

## REFERENCES

1. Broman, T., Forssman, B., and Olsson, O. Further experimental investigations of injuries from contrast media in cerebral angiography. Summation of various injurious factors. *Acta radiol., Stockh.*, 1950, *34:* 135–143.
2. Broman, T., and Lindberg-Broman, A. M. An experimental study of disorders in the permeability of the cerebral vessels ("the blood-brain barrier") produced by chemical and physico-chemical agents. *Acta physiol. scand.*, 1945, *10:* 102–125.
3. Broman, T., and Olsson, O. The tolerance of cerebral blood-vessels to a contrast medium of the diodrast group. An experimental study of the effect on the blood-brain-barrier. *Acta radiol., Stockh.*, 1948, *30:* 326–342.
4. Broman, T., and Olsson, O. Experimental study of contrast media for cerebral angiography with reference to possible injurious effects on the cerebral blood vessels. *Acta radiol., Stockh.*, 1949, *31:* 321–334.
5. Ekström, G., and Lindgren, A. G. H. Gehirnschädigungen nach cerebraler Arteriographie mit Thorotrast. *Zbl. Neurochir.*, 1938, *3:* 227–248.
6. Engeset, A. Cerebral angiography with perabrodil (carotis angiography), *Acta radiol., Stockh.*, 1944, suppl. 56, 207 pp.
7. French, L. A., and Blake, P. S. Complications following the use of neo-iopax in cerebral angiography. *Amer. J. Roentgenol.*, 1950, *64:* 816–818.
8. Friedemann, U. Blood-brain barrier. *Physiol. Rev.*, 1942, *22:* 125–145.
9. Green, J. R., and Arana, R. Cerebral angiography. A clinical evaluation based on 107 cases. *Amer. J. Roentgenol.*, 1948, *59:* 617–650.
10. Hodes, P. J., Perryman, C. R., and Chamberlain, R. H. Cerebral angiography. *Amer. J. Roentgenol.*, 1947, *58:* 543–582.
11. Kristiansen, K., and Cammermeyer, J. An experimental investigation on the effect of arteriography with perabrodil on the brain. *Acta radiol., Stockh.*, 1942, *23:* 113–130.
12. Northfield, D. W. C., and Russell, D. S. The fate of thorium dioxide (thorotrast) in cerebral arteriography. *Lancet*, 1937, *1:* 377–381.
13. Olsson, O. Cerebral angiography: tolerance for contrast media of diodrast type. *J. Neurol. Neurosurg. Psychiat.*, 1949, n.s. *12:* 312–316.
14. Wilkinson, M., Stanton, J. B., Jones, D. P., and Spalding, J. M. K. Percutaneous carotid angiography. A team technique. With a report of the results in seventy cases. *J. Neurol. Neurosurg. Psychiat.*, 1949, n.s. *12:* 183–186.

# CASE REPORTS AND TECHNICAL NOTES

## TUBERCULOUS OPTICOCHIASMATIC ARACHNOIDITIS

### REPORT OF A CASE*

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(Received for publication November 27, 1950)

The surgical freeing of arachnoidal adhesions about the optic chiasm was first described by Balado[1] in 1929 and this condition is often referred to in the South American literature as Balado's disease. In 1931 Heuer and Vail[6] reported a series of cases in which trauma or infection was the probable cause. These authors emphasized early operative intervention. Since that time the syndrome of opticochiasmatic arachnoiditis has become well known.[2,4,8] In many succeeding reports the etiology has remained obscure.[2,3,8] In 1937 Hausman[5] mentioned 5 cases all thought to be due to syphilis of the central nervous system. Bruetsch[2] in his review of the subject listed trauma, infections of the facial cavities and nonpurulent cerebromeningeal infections as among the leading causes.

Our case represents the first case of opticochiasmatic arachnoiditis that was proven due to tuberculosis and surgically treated. One can merely conjecture that this may be due to the high mortality rate in tuberculous meningitis prior to the advent of streptomycin therapy. Ivey, Phillips and Meirowsky[7] recently reported the successful extirpation of a cerebellar fibrocaseous tuberculoma. These authors stated that intramuscular and intrathecal streptomycin may encourage surgical extirpation of tuberculous lesions of the brain. It seems also likely that as antibiotic therapy advances, chronic arachnoiditis may be more commonly met with in the future as the immediate mortality rate falls and the later sequelae appear.

#### CASE REPORT

#172126. J.G., a 25-year-old Mexican male laborer was admitted on Oct. 12, 1948. Seven months previously a "boil" on the left side of his neck had been lanced. This continued to drain serosanguinous fluid for several months and finally healed spontaneously. Two weeks prior to admission he began to have generalized headaches, which became progressively more intense and were accompanied by stiffness of the neck and low-grade fever. For the last several days he had been severely nauseated and unable to retain food or fluids. There was no history of convulsions nor of exposure to tuberculosis.

*Examination.* The patient appeared acutely ill. Temperature 103°, pulse 110, respirations 22. B.P. 130/90. Abnormal physical findings were limited to strongly positive Kernig's and Brudzinski's signs, horizontal and vertical nystagmus, and pathological plantar responses on the left. RBC 4,100,000; WBC 8,500, with a normal differential, and a sedimentation rate of 23 mm./hr. Urinalysis and serology negative.

* Reviewed by the Veterans Administration and published with the approval of the Chief Medical Director. The statements and conclusions of the authors are the result of their own study and do not necessarily reflect the opinion or policy of the Veterans Administration.

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*Hospital Course.* Lumbar puncture on admission revealed turbid and xanthochromic CSF with a pressure of 190 mm. of water and normal dynamics. The CSF contained RBC 28; WBC 913, with 75 per cent lymphocytes; sugar 25 mg. per cent; total protein 368 mg. per cent; globulin 4+; chlorides 640 mg. per cent; Wassermann negative, and colloidal gold curve 2355544443. A thick pellicle formed rapidly which failed to reveal acid-fast bacilli both on smear and culture. The chest x-ray was negative for evidence of pulmonary tuberculosis.

The patient was treated with streptomycin, promin, parenteral fluids and bed rest. During the first 10 hospital days he steadily improved and the temperature fell to normal. On the 16th day, however, he began to complain again of severe headaches, became nauseated and vomited continuously. He went progressively downhill, became mentally clouded, actively hallucinated, incontinent, and had rapid, successive, generalized convulsions. Repeated examinations revealed no papilledema or other neurological changes.

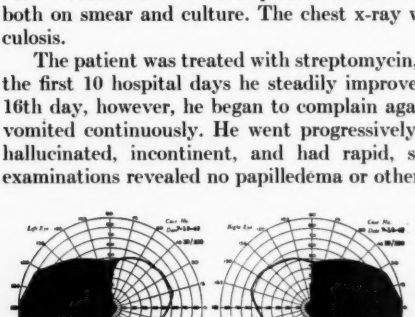

FIG. 1. Visual fields 2 months before operation, showing symmetrical bitemporal hemianopsia.

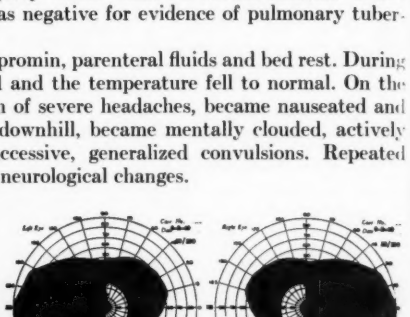

FIG. 2. Visual fields 1 month before operation, showing progressive constriction, and loss of central vision.

Despite intensive therapy in the succeeding weeks there were repeated bouts of stupor, high temperature, convulsions, and nuchal rigidity. Left facial nerve palsy of infranuclear type developed. The CSF protein continued to be elevated; on one occasion it was 6,400 mg. per cent. Repeated cultures and smears remained negative for acid-fast bacilli.

Over a period of several months the patient gradually improved, became lucid and coherent, and his temperature again returned to normal. However, he continued to have occasional, generalized convulsions without localizing signs. The facial nerve palsy disappeared spontaneously. He was given dilantin and phenobarbital which controlled his convulsive attacks. In June 1949, 9 months after admission, he first complained of diminished vision without associated headaches, nausea or vomiting, or temperature elevation. At this time there was evidence of early primary optic atrophy. No papilledema or retinal hemorrhages were noted. Visual field studies revealed a bitemporal hemianopsia (Fig. 1). Serial visual field studies showed a rapid progressive loss of both peripheral and central vision (Fig. 2). In addition, the optic pallor increased. Roentgenograms of the skull revealed a normal sella turcica.

*Operation.* On Sept. 13, 1949 a subfrontal chiasmal exploration was performed. The optic nerve and chiasm were found to be surrounded by dense, matted adhesions of leptomeninges. Both optic nerves were markedly flattened and the chiasm was densely bound down at the base of the brain. The adhesions were carefully divided across the chiasm and both the chiasm and optic nerves were liberated.

*Postoperative course* was smooth and uneventful. His temperature remained normal and he had no further headaches, vomiting or convulsions. Repeated examinations revealed progressive and dramatic improvement in the peripheral visual fields and visual acuity (Fig. 3). Objectively, there was no change in the optic atrophy. He was discharged to the Chest Medical Service on Oct. 24, 1949.

Shortly thereafter a review of his previous chest x-rays revealed a destructive process involving the body of the 11th thoracic vertebra and a paraspinal abscess, which apparently had been present since December 1948, and had been overlooked. Coincident with this,

there developed severe pain in both his legs and hips and a left foot drop. On Nov. 18, 1949 a paraspinal abscess was drained. He did not improve. Serial x-ray examination revealed extension of the abscess, and on Dec. 20, 1949 another incision and drainage was carried out. The wound failed to heal and continued to drain purulent material. In January 1950 x-ray of the chest showed a soft area of pneumonic infiltration in the left base. Sputum cultures and smears showed acid-fast bacilli. Despite intensive therapy with PAS, streptomycin, and thiosemicarbazone the patient ran a slow, progressive, downhill course. Re-examination 1 month before death revealed no gross contraction of the visual fields or alteration of the visual acuity.

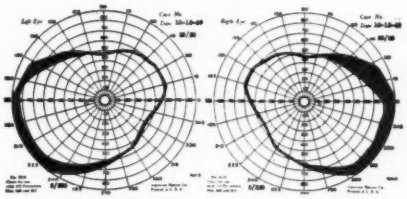

FIG. 3. Visual fields 1 month postoperatively, showing dramatic return of vision.

Nuchal rigidity and tetanic convulsions developed, and following a brief period of coma the patient expired on March 11, 1950.

*Autopsy.* Extensive, disseminated, arachnoiditis was present over the entire brain stem and base of the brain. Caseo-cavernous tuberculosis was present in both lungs. Miliary nodules were found in the spleen and kidneys.

## COMMENT

Although this patient died of widely disseminated tuberculosis, two important points need emphasis. The gratifying and dramatic improvement in his visual fields remained until death. At autopsy the optic nerves and chiasm remained remarkably free of arachnoidal adhesions, although such were found over the rest of the base of the brain. In retrospect, it appears that the focus of infection in the 11th thoracic vertebra was of far more importance as the cause of death than the operative procedure. One might almost conjecture that had the tuberculosis of the spine been controlled, the patient may well have survived.

## SUMMARY

1. A brief review of opticochiasmatic arachnoiditis has been reported.

2. A case of tuberculous meningitis with secondary involvement of the optic chiasm has been reported. Surgical liberation of the adhesions was successfully performed.

## REFERENCES

1. BALADO, M., and SATANOWSKY, P. Tratamiento quirúrgico de la atrofia de la papila. *Arch. argent. Neurol.*, 1929, *4:* 71–75.
2. BRUETSCH, W. L. Etiology of optochiasmatic arachnoiditis. *Arch. Neurol. Psychiat., Chicago*, 1948, *59:* 215–228.
3. CRAIG, W. M., and LILLIE, W. I. Chiasmal syndrome produced by chronic local arachnoiditis. Report of eight cases. *Arch. Ophthal., N.Y.*, 1931, 2 s. *5:* 558–574.
4. HARTMANN, E. Optochiasmatic arachnoiditis. *Arch. Ophthal., N.Y.*, 1945, 2 s. *33:* 68–77.
5. HAUSMAN, I. Syphilitic arachnoiditis of the optic chiasm. *Arch. Neurol. Psychiat., Chicago*, 1937, *37:* 929–958.
6. HEUER, G. J., and VAIL, D. T., JR. Chronic cisternal arachnoiditis producing symptoms of involvement of the optic nerves and chiasm. Pathology and results of operative treatment in four cases. *Arch. Ophthal., N.Y.*, 1931, 2 s. *5:* 334–349.
7. IVEY, D., PHILLIPS, S., and MEIROWSKY, A. M. Fibrocaseous cerebellar tuberculoma. Surgical resection in conjunction with streptomycin therapy. *J. Neurosurg.*, 1950, *7:* 370–373.
8. WAGENER, H. P. Optochiasmatic arachnoiditis. *Amer. J. med. Sci.*, 1939, n.s. *197:* 270–276.

# CHRONIC OR SUBACUTE SUBDURAL HEMATOMA DUE TO INDIRECT HEAD TRAUMA

## REPORT OF TWO CASES*

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Practically all cases of chronic subdural hematoma are due to some type of *direct* head injury. Grinker[9] well epitomizes most modern accounts of the lesion under consideration in his book: "Chronic subdural hematoma occurs after head trauma with severe skull fracture, or very mild concussion. Alcoholism and psychosis, conditions which afford frequent opportunities for head injury, are predisposing causes."

Cases of chronic or of subacute subdural hematoma *not due* to a *direct* blow on the *head* appear to be rare, or at least a survey of current literature having to do with a consideration of head injury in all its aspects, or to neurology and neurosurgery in general, would lead one so to believe. In a careful survey of the world's current medical literature as listed in the *Quarterly Cumulative Index Medicus* for the past 10 years, only a single instance of a chronic subdural hematoma due to *indirect* trauma was encountered and the mode of the indirect injury was not given in the title of the paper,[10] which was inaccessible to the writer. Likewise, in a thorough review of a number of recent books[5,7,9,11,12] on neurology, neuropathology and neurosurgery, including two[4,14] devoted entirely to head and spinal injuries, only one reference[7] to chronic subdural hematoma from *indirect trauma* (not including the head) was encountered: Loyal Davis[7] mentions a fall on the buttocks as the only known trauma in certain cases of chronic subdural hematoma. He refers to this type of injury in general terms in a discussion in his book of the causes of chronic subdural hematoma, not detailing a specific case. It happens that the 2 cases to be described in this paper were due to this etiological factor. Neither patient was an alcoholic or psychotic, and both were highly intelligent, so that an accurate history with respect to trauma of any kind was possible in each of the two cases. It seems certain that neither of the patients had a direct blow on the head in the immediate or remote past before being admitted to the hospital for operation. This was determined by repeated questioning of the patients and their families. Both patients had had a fall on the buttocks as the precipitating factor in the production of symptoms and signs due to a chronic or subacute subdural hematoma.

This is of considerable interest as it is generally believed today that this lesion in adults is almost invariably caused by a direct blow on the head, usually in an anteroposterior direction, thus tearing one or more of the short communicating veins between the dura and the cortex near the falx, resulting in a subdural hematoma.

There are, of course, reports of subdural hematoma scattered throughout the literature of the last decade or more describing its development in children or adults with no definite traumatic history, that is, spontaneous[8] in type, the clot being ascribed to scurvy, blood dyscrasia, meningitis or other intracranial infection, etc.

* Read at the Annual Meeting of the American Academy of Neurological Surgery, held at the Mayo Clinic, Rochester, Minnesota, September 28, 1950.

Wechsler[15] and others[1,2,3] refer to certain subdural hematomas occurring after blast injuries up to 100 ft. distant on the ground or even under water, in which there had been no direct head injury except by the pressure wave. Peet[13] quotes Grant's case caused by the relatively mild trauma from ocean breakers while surf bathing. None of these rarer causes of subdural hematoma was an etiological factor in the 2 cases to be reported in this paper.

## CASE REPORTS

Case 1. *Mrs. L.S., 54-year-old white housewife. Admitted Jan. 30, 1950. Fall on buttocks 9 days previously. Development of large left subacute subdural hematoma. Evacuation by means of subtemporal decompression. Discharged improved Mar. 2, 1950. Recovery after long period of aphasia.*

The patient, a large heavy woman, had fallen down a flight of 6 steps while visiting her daughter's new home, the steps of which had recently been polished. She was a known hypertensive. Her feet slipped from under her and she came down rather violently in a sitting position. She did not strike her head at any time. She felt no immediate ill effects. She was not rendered unconscious, even momentarily, at the time of the fall. Within 4 hours of the accident, however, she had severe headache (frontal), associated with drowsiness, nausea and vomiting. She became disoriented and mentally confused. Within 15 hours of the accident, weakness of the right upper and lower extremities was noted. Within 2–3 days of the injury, blurred vision and diplopia supervened. The right leg was definitely weaker than the right arm. She was aphasic when admitted to the hospital 9 days after injury. Fortunately, she was left-handed.

*Examination.* B.P. was 200/120, T. 99° R, P. 56–60/m. R. 18/m. She was drowsy but responded fairly satisfactorily to questioning. Motor aphasia was obvious. There was bilateral choked disk of moderate degree, more marked on the left. The right leg could not be flexed at the knee. The right arm was also weak but less so than the leg. Skull films showed the pineal gland to be deflected to the right and downward, suggesting a left-sided space-occupying lesion.

*Operation* (novocaine anesthesia) on day of admission. Bilateral superior temporal burr openings were made: the one on the right side showed the brain to be firmly approximating the dura. On the left, a typical subdural hematoma was encountered and evacuated by means of a subtemporal decompression. The clot was dark and tarry in consistency and amounted to at least 3 ounces. The brain was slightly contused on the surface just above and posterior to Broca's area.

Her *postoperative course* was somewhat stormy, characterized by considerable fever, and the development of auricular fibrillation, which responded to digitalis. For 2 weeks at least, the aphasia and weakness of the right side were *more* marked than *before* operation. Recovery thereafter was slow but steady. The wounds healed per primam and no further operative procedures were necessary.

*Follow-up Notes.* On April 28, 1950 (almost 3 months after operation) the patient returned in excellent condition. However, there was marked nominal aphasia. She could sing nevertheless, and protrude her tongue on command, which many aphasics cannot do. There was very satisfactory motor power of the right arm and leg, and no headache, vertigo or diplopia. She looked very well, and was cheerful and quite cooperative. On July 25, 1950 (almost six months after operation) her condition remained the same except for improvement in speech. There was no demonstrable weakness of the right arm and leg. The subtemporal decompression on the left side was flat (even concave) and she had no subjective complaints of any kind. She was actively engaged in her household duties.

Case 2. *Mr. L.B., 64-year-old assistant commissioner of agriculture. Admitted Mar. 20, 1950. Fall on buttocks several weeks previously; the accident almost forgotten. Left subdural hematoma removed in two-stage procedure. Discharged improved April 9, 1950. Early complete recovery without residual neurological deficit.*

The patient had first been seen at his home a few days before admission because of headache and mental confusion. At that time no history of injury could be elicited. Cerebral vascular disease or an early tumor was therefore suspected. As he did not improve with symptomatic treatment at home, he was hospitalized. On the morning of operation his wife, for the first time since being interviewed about his illness, suddenly remembered a sharp fall on the buttocks which the patient had sustained on the cellar steps several weeks before admission. He had made light of the injury at the time but had had headache for 1–2 days immediately thereafter which did not prevent his working as usual. He and his family apparently completely forgot the episode, until the morning of operation.

*Examination.* B.P. was 180/100, T. 99.6° R, P. 64/m. R. 20/m. The patient was disoriented as to time. There was no choking of the disks or pupillary inequality. Severe headache was obvious. There was no relative weakness of the extremities but there was a bilateral positive Babinski and Hoffmann sign. The patient was right-handed. At times he lapsed into semi-consciousness.

*1st Operation,* Mar. 21. 1950 (day after admission). Bilateral frontal burr openings were made (novocaine anesthesia) preliminary to previously planned ventriculography. A typical subdural hematoma was encountered on the left side and evacuated. Through an additional burr opening in the left temporal region 60 cc. of dark, tarry blood escaped as soon as the dura was opened and a further quantity was removed through irrigation and rotation of the head. The cortex was 3–4 cm. from the dura; 100 cc. of normal saline solution were introduced into the right lateral ventricle to expand the brain.

*Course.* Two days later the patient was almost in extremis. He had marked and typical Cheyne-Stokes' respiration, and could not be aroused.

*2nd Operation.* A left subtemporal decompression was carried out; also a right temporal burr opening was made to rule out completely a subdural hemorrhage on the right side (negative findings). The clot overlying the left cerebral hemisphere was organized for the most part and considerably older in appearance than that in Case 1. As soon as the operation was begun and the dura opened more widely to permit of removal of the solid clot (under endotracheal ether anesthesia), the Cheyne-Stokes' respiration disappeared.

*Course.* The patient thereafter improved rapidly except for considerable mucus in his tracheo-bronchial tree, a frequent complication in our experience after evacuation of a chronic subdural hematoma.[6] Four days after the 2nd operation, he was conscious and rational and able to speak a few words. His wounds healed per primam and he left the hospital 17 days after the 2nd operation in excellent condition. The left-sided decompression was concave, the motor power in the right arm and leg was normal and he had very slight aphasia.

He has since improved in every way and has returned to his work in the State Department of Agriculture.

*Comment.* Curiously enough, the *aphasia*—present in each instance, due to a large left-sided subdural hematoma—was much more marked and persistent in the left-handed woman of Case 1, than in the right-handed man of Case 2.

## SUMMARY

Two cases of subdural hematoma—one subacute (Case 1) and one chronic (Case 2)—are reported, due to *indirect head trauma*, i.e., a fall on the buttocks in each instance. The almost complete absence of similar reports in the literature, both in current journals and in neurological and neurosurgical works, is cited. Each patient made a satisfactory recovery after evacuation of the subdural hematoma overlying the left cerebral hemisphere.

## REFERENCES

1. Abbott, W. D., Due, F. O., and Nosik, W. A. Subdural hematoma and effusion as a result of blast injuries. First preliminary report. *J. Amer. med. Ass.*, 1943, *121:* 664–666. Second preliminary report. Diagnosis by psychiatric examination. *Ibid.*, 739–741.

2. Abbott, W. D., Due, F. O., and Nosik, W. A. Psychiatric diagnosis of subdural hematoma and effusion from blast. *Amer. J. Psychiat.*, 1943, *100:* 98–104.
3. Abbott, W. D., Due, F. O., and Nosik, W. A. Subdural hematoma and effusion as result of blast injuries. *Bull. Amer. Coll. Surg.*, 1943, *28:* 123–125.
4. Alpers, B. J. Cerebral birth injuries. In: *Injuries of the skull, brain and spinal cord. Neuro-psychiatric, surgical, and medico-legal aspects.* S. Brock, Ed. Baltimore: Williams & Wilkins Co., 1943, 2nd ed., ix, 616 pp. (see pp. 208–210).
5. Alpers, B. J. Clinical neurology. *Philadelphia: F. A. Davis Co.*, 1945, xii, 797 pp.
6. Coleman, C. C. Chronic subdural hematoma: diagnosis and treatment. *Amer. J. Surg.*, 1935, n.s. *28:* 341–363 (see Case IV).
7. Davis, L. The principles of neurological surgery. *Philadelphia: Lea & Febiger*, 1946, 3rd ed., 540 pp. (see p. 99).
8. Feld, M. Contribution à l'étude des hématomes sous-duraux spontanés. *Rev. neurol.*, 1947, *79:* 97–108.
9. Grinker, R. R. Neurology. *Springfield, Ill.: Charles C Thomas*, 1944, 3rd ed., ix, 1136 pp. (see p. 956).
10. Léchelle, P., Petit-Dutaillis, D., and Thévenard, A. Hématome sous-dural post-traumatique sans traumatisme direct de la tête. Trépanation. Guérison. *Bull. Soc. méd. Hôp. Paris.* 1946, *62:* 45–47.
11. Lichtenstein, B. W. A textbook of neuropathology. With clinical, anatomical and technical supplements. *Philadelphia: W. B. Saunders Co.*, 1949, xviii, 474 pp. (see pp. 184–185).
12. Nielsen, J. M. A textbook of clinical neurology. *New York: P. B. Hoeber, Inc.*, 1946, 2nd ed., xi, 699 pp. (see pp. 545–547).
13. Peet, M. M. Extradural hematoma, subdural hematoma, subdural hydroma. In: *Injuries of the skull, brain and spinal cord. Neuro-psychiatric, surgical, and medico-legal aspects.* S. Brock, Ed. Baltimore: Williams & Wilkins Co., 1943, 2nd ed., ix, 616 pp. (see pp. 134–145).
14. Rowbotham, G. F. Acute injuries of the head. Their diagnosis, treatment, complications and sequels. *Baltimore: Williams & Wilkins Co.*, 1945, 2nd ed., xvi, 424 pp. (see pp. 142–147).
15. Wechsler, I. S. A textbook of clinical neurology with an introduction to the history of neurology. *Philadelphia: W. B. Saunders Co.*, 1947, 6th ed., xv, 829 pp. (see p. 536).

## HEMANGIOBLASTOMA OF CEREBELLUM WITH POLYCYTHEMIA

### CASE REPORT

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(Received for publication December 27, 1950)

Neurological signs and symptoms are frequently associated with primary polycythemia due to the vascular complications characteristic of this disease. Conversely, instances of intracranial neoplasms with an associated secondary polycythemia have been reported in the literature.

The occurrence of expanding subtentorial lesions with polycythemia is extremely rare. Oppenheimer[3] reported a case of polycythemia and cerebellar medulloblastoma. Two cases of hemangioblastoma of the cerebellum and polycythemia were reported by Carpenter, Schwartz, and Walker.[1] Both of their patients had remission of the polycythemia following removal of the hemangioblastoma. An excellent review of the literature on neurogenic polycythemia was given by Drew and Grant[2] in 1945. They added 1 case, the intracranial lesion being a subdural hematoma. The polycythemia in their patient, however, showed signs of returning after 5 months.

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CASE REPORT

C.M., aged 24, a second lieutenant in the infantry, was admitted to the U. S. Army 70th General Hospital on Aug. 9, 1944. He had been evacuated from the 29th Station Hospital and was flown from Algiers to Oran. On admission, he was conscious but spoke very slowly and in a monotonous tone. P. was 60/min., R. 11/min; B.P. normal. He seemed well oriented but was not alert. When taken by litter to the x-ray department, he began to scream with pain and afterwards complained of persistent severe headache. Later in the evening he became very drowsy and stuporous, but improved slowly after intravenous administration of 50 per cent glucose. The next morning he had projectile vomiting. The officer who had accompanied him from Algiers stated that the patient had deteriorated mentally over a period of about 4 months and particularly during the 7 days before admission.

The patient's illness began in October, 1943, with severe throbbing occipital headaches which persisted. For the last few months he had noticed difficulty in reading, blurring of vision, and diplopia. He had been troubled by dizziness and stumbling, particularly to the right, and there seemed to be some slowing of his speech. He had been in another general hospital in January, 1944, and in a station hospital in February 1944 with the chief complaint of headache. He was discharged both times with a diagnosis of psychoneurosis. He was readmitted to the 29th Station Hospital on Aug. 2, 1944. A lumbar puncture was done there and following this he became much worse, being stuporous a good deal of the time.

*Examination.* He was a moderately drowsy but easily aroused individual talking in a monotonous tone. There was no aphasia, ataxia, or asynergism. He had nystagmus right and left, and marked bilateral papilledema with exudate. There was a right facial weakness with hypesthesia. The tendon reflexes were slightly hyperactive on the right. Babinski reaction was present bilaterally. There was incoordination of the arm and hand with past pointing with both hands. Heel-to-knee tests were performed fairly well.

RBC was 4,790,000; Hb. 13.5 gm. (90 per cent). Leucocyte and Schilling counts were normal. Clotting time was 7 min.; bleeding time, 3 min. X-rays of skull were negative.

*1st Operation.* On Aug. 9, 1944, preliminary ventriculography through the right posterior horn (80 ml. of fluid removed and replaced with air) showed a dilated ventricular system with a large 3rd ventricle. Cerebellar craniotomy was then done. After the dura had been opened over both cerebellar hemispheres and the occipital sinus ligated and cut, a cystic tumor was seen in the left hemisphere, extending down into the cerebellar tonsil. The cyst was evacuated. Then, using lighted retractors, it was completely explored, but no nubbin of tumor or evidence of hemangioma was found.

*Postoperative Course.* The patient did very well. Two lumbar punctures were done because of slightly bloody CSF, but otherwise his course was uneventful. He was evacuated to the zone of interior, and was given a medical discharge from the army.

*Subsequent Course.* He was asymptomatic in every respect until 1948, when he wrote that his symptoms were beginning to reappear. Accordingly, we advised him to enter the U.S. Veterans Hospital at Jefferson Barracks, Missouri. He was admitted on June 11, 1948. He had been entirely well until about 2½ months previously, when he first suffered persistent, dull headaches, partially controlled by headache powders. Following this he noticed a return of visual disturbances, particularly difficulty in focusing. There was a tendency to stagger on walking and true vertigo on leaning forward. The symptoms were especially prominent during the last 2½ weeks.

*Examination.* Positive neurological findings were: nystagmus on looking to the right, markedly positive Romberg test, and staggering gait. Fundoscopic examination by the ophthalmological consultant revealed no abnormalities.

RBC was 7,890,000; Hb. 21.1 gm. (136 per cent); hematocrit cell volume per cent 69. Leucocyte count was 6,850, with normal Schilling count; platelet count was 645,000. Repeated RBC was 7,820,000; Hb. 21.9 gm. (136 per cent). Kahn reaction was negative.

Roentgenograms of the skull showed only the old cerebellar craniectomy wound. Films

of the chest revealed an area of increased opacity in the left apex; the radiologists were unable to determine the state of its activity.

*2nd Operation.* On June 16, 1948, the cerebellar craniotomy wound was reopened. A large bluish, pulsating mass occupied the whole left half of the posterior fossa. This mass was made up of extremely large, thin-walled blood vessels. It was gradually completely removed, the vessels being coagulated and broken, and the bleeding points secured with electrocautery.

*Microscopic Examination.* "The section discloses an angiomatous tumor consisting of blood channels ranging in size from immense cavernous structures to minute capillaries or sinus-like vessels. There are relatively solid areas consisting of clumps of cells forming a sort of syncytium. Cytoplasm is clear; the nuclei are round or oval and pale. In some areas slit-like vessels are apparent."

*Diagnosis:* Hemangioblastoma.

*Postoperative Course.* Immediately after operation, his RBC fell to 5,960,000, with 17.8 gm. Hb. (115 per cent). On June 29, 1948, 13 days postoperative, RBC was 4,800,000; Hb. 16 gm. (103 per cent). His course was uneventful and he was discharged on July 14, 1948.

*Subsequent Note.* At the present time the patient is in the U.S. Veterans Hospital, Bay Pines, Florida, because of activation of the tuberculous lesion previously noted. Reports from this hospital of the patient's erythrocyte count and hemoglobin are included in Table 1.

TABLE 1

(Case C.M.)

| Date | RBC (c.mm.) | Hb. | WBC (c.mm.) | Differential, Hematocrit, Etc. |
|---|---|---|---|---|
| 8- 8-44 | 4,790,000 | 90% | 9,000 | Polys. 70%, Lymph. 22%, Schilling 100, Baso. 1, Eosin. 2. Clotting, 7 min. Bleeding, 3 min. |
| 8- 9-44 | *Operation: removal of cerebellar cyst* | | | |
| 6-11-48 | 7,890,000 | 136% 21.1 gm. | 6,850 | Neutro. 59, Lymph. 40%, Eosin. 1, Hematocrit 69. |
| 6-11-48 repeat | 7,820,000 | 136% 21.9 gm. | | Platelets 640,000 |
| 6-16-48 | *Operation: removal of hemangioblastoma* | | | |
| 6-16-48 | 5,960,000 | 115% 17.8 gm. | | |
| 6-17-48 | 5,630,000 | 118% 18.3 gm. | | |
| 6-29-48 | 4,800,000 | 103% 16.0 gm. | | |
| 2-10-50 | 4,270,000 | 86% | | |
| 3- 3-50 | 4,520,000 | 90% | | |
| 3-27-50 | 4,500,000 | 92% | | |
| 4- 3-50 | 4,750,000 | 94% | | |

SUMMARY

The third reported case of hemangioblastoma of the cerebellum with associated polycythemia is presented. The patient had a complete remission of the polycythemia after the removal of a large hemangioblastoma. It will be noted that the polycythemia did not develop until after the large hemangioma was demonstrable. There was no evidence of such lesion at the first operation. His red blood cell count and hemoglobin values have remained normal to the present date.

REFERENCES

1. Carpenter, G., Schwartz, H., and Walker, A. E. Neurogenic polycythemia. *Ann. intern. Med.*, 1943, *19:* 470–481.
2. Drew, J. H., and Grant, F. C. Polycythemia as a neurosurgical problem. A review, with reports of two cases. *Arch. Neurol. Psychiat., Chicago*, 1945, *54:* 25–36.
3. Oppenheimer, B. S. Vascular occlusion in polycythemia vera. *Trans. Ass. Amer. Phys.*, 1929, *44:* 338–344.

## A SIMPLIFIED APPARATUS FOR CONSTANT VENTRICULAR DRAINAGE

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(Received for publication November 8, 1950)

Several techniques for effecting constant ventricular drainage have been described.[1,3,4,5] Any successful routine method should be easily available at all times, provide a means of measuring and controlling the intracranial pressure and the amount of ventricular fluid drained, afford maximum protection against infection and be well tolerated by the patient. An apparatus that meets these requirements has been developed by the neurosurgical services of The Peter Bent Brigham Hospital and The Children's Hospital, Boston.

The apparatus consists of the following parts: (A) an ordinary graduated 1 liter Fenwal intravenous bottle which is held inverted by a ring attached to the head of the patient's bed; (B) a "J"-shaped double lumen glass tube which fits the standard Fenwal single hole rubber stopper and extends into the bottle about 22 cm.; (C) connecting rubber tube attached to the glass tube at one end and a glass adapter and standard intravenous needle at the other; (D) a 12-inch length of small-caliber polyethylene tubing,[2] which is used as the ventricular catheter. All of this except the polyethylene tubing is sterilized as a unit; several units are kept available at all times.

To institute drainage, a ventricular tap is made in the usual fashion using an open-end needle fitted with a stylet. When a free flow of fluid has been obtained the polyethylene catheter is threaded into the ventricle through the needle and the needle withdrawn, leaving the catheter in place. An intravenous needle of proper size is inserted into the end of the catheter and attached to a 1 cc. syringe. When adequate flow of ventricular fluid through the catheter is assured it is anchored to the skin with stitch and a sterile dressing is applied to the head around the catheter. The needle is then removed from the syringe and attached to the tubing from the drainage bottle. The bottle is usually positioned so that the curved top of the glass tube is about 150 mm. above the formen magnum, but any desired pressure can be maintained by raising or lowering the bottle. If the rubber connecting tube is passed over a pulley at the head of the bed and a small weight attached to the bottom of the hanging loop, the patient has considerable freedom of motion without tension on the ventricular catheter. To protect against kinking and tearing, the polyethylene catheter should be reinforced with adhesive tape where it receives the intravenous needle. The system is shown diagrammatically in Fig. 1.

### COMMENT

During a 9-month period from June 1949, to April 1950, this type of drainage was used on 26 patients 29 times. The diagnoses in these cases included brain tumor, brain abscess, hydrocephalus of various types, myelomeningocele with Arnold-Chiari malformation, and tuberculous meningitis. The duration of drainage, dictated by the clinical requirements of the patient, was usually 8 days or less (21

patients). However, 2 patients were on drainage for 10 days and 6 patients were on drainage for 15 to 18 days.

In 3 patients drainage was complicated by ventriculitis; the most severe case, manifest the day drainage was started, was probably the result of a gross breach of technique in instituting the drainage. The other 2 cases of ventriculitis, which did not appear until the 5th and 6th days respectively, were associated with moving the patient for special diagnostic procedures requiring the temporary removal of the patient from the drainage bottle. All of these patients responded to penicillin therapy. In 1 patient there developed a sterile pleocytosis of the cerebrospinal fluid associated with a fever of 102° F. Both the fever and the pleocytosis vanished when

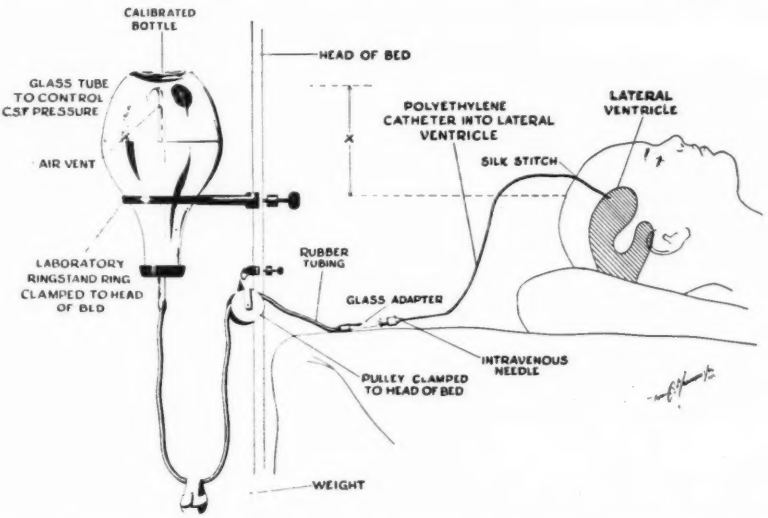


FIG. 1. Diagram of constant ventricular drainage apparatus in use. (X) The height of the top of the tube above the ventricle determines the intracranial pressure.

the drainage was removed. Occasionally when drainage had been placed for long periods there was some maceration and inflammation of the skin around the polyethylene catheter. This cleared up quickly when the catheter was removed or shifted to another site.

Varying the level of the drainage bottle has been particularly valuable in determining whether patients no longer need external drainage. With the bottle well elevated the drainage can be effectively stopped, but easily reinstated by lowering the bottle if untoward symptoms develop.

This apparatus has been useful in administering constant intraventricular antibiotic therapy. A constant drip of the desired antibiotic was directed into one ventricle while constant drainage was maintained from the other. By proper adjustment of the bottle, the intraventricular pressure was held at a physiological level throughout the period of therapy.

The length of time a patient has been kept on drainage has been dictated by

his clinical state. This has in many instances meant periods of 2 weeks or longer on continuous drainage.

Acknowledgment is gratefully made to Mr. K. R. Aikens of Macalaster Bicknell for his assistance in the manufacture of the double lumen glass tubes. These tubes are available in quantity from the Macalaster Bicknell Company, 243 Broadway, Cambridge, Massachusetts.

REFERENCES

1. Crawford, A. S., and Munslow, R. A. A method of prolonged ventricular drainage. *Ann. Surg.*, 1943, *117:* 798–799.
2. Ingraham, F. D., Alexander, E., Jr., and Matson, D. D. Polyethylene, a new synthetic plastic for use in surgery. *J. Amer. med. Ass.*, 1947, *135:* 82–87.
3. Ingraham, F. D., and Campbell, J. B. An apparatus for closed drainage of the ventricular system. *Ann. Surg.*, 1941, *114:* 1096–1098.
4. Poppen, J. L. Ventricular drainage as a valuable procedure in neurosurgery. Report of a satisfactory method. *Arch. Neurol. Psychiat., Chicago*, 1943, *50:* 587–589.
5. Robinson, F. An apparatus for continuous ventricular drainage and intraventricular therapy. *J. Neurosurg.*, 1948, *5:* 320–323.

## THE STEREOENCEPHALOTOME

### (MODEL III OF OUR STEREOTAXIC APPARATUS FOR OPERATIONS ON THE HUMAN BRAIN)

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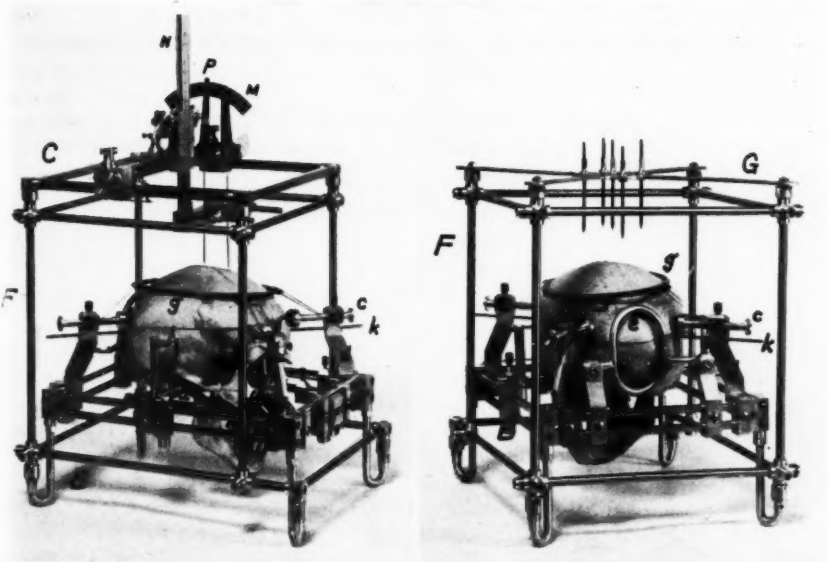
(Received for publication November 11, 1950)

The first stereotaxic apparatus (stereoencephalotome) described by us (1947) for operations on the human brain was fixed to the skull by means of a plaster cast.[2] A second instrument (1949) had a metallic base.[3] From it the present model has been developed which has the following advantages: 1) relatively low weight (5.52 lbs.); 2) great rigidity; 3) it can be easily mounted to the skull at operation in exactly the same position as at the pre-operative x-ray study; 4) the electrodes may be inserted into the brain from the top, the dorsal or either lateral aspect of the skull; 5) it has a multiple electrode holder.

The present model consists of four parts: a base (B); a frame (F) which attaches to the base; an electrode carrier (C) which is mounted on a square frame; a gauge (G) which carries five movable calibrated pins (Figs. 1 and 2). Alignment of the base parallel to Reid's base line is obtained by ear plugs (a) and orbital bars (b), fixation to the skull by rubber-cushioned stops (c) on supports (d), an occipital rest (e) and a maxillary support (f) and a ring (g) suspending the base by graduated steel tapes (replaced by strings in Figs. 1 and 2). Identical application during roentgenography and operation is insured by graduated pins (i, k) on the base and on the gauge (G). The points where these pins touch the scalp are tattooed before roentgenography. At the operation the pins must touch the corresponding tattoo marks at exactly the same calibrated distances as they did previously. The frame (F) is so constructed that the electrode carrier (G) can be placed on its posterior, top or either lateral aspect. Up to 15 electrodes may be inserted into the brain in any of these positions at angles between 0–45° on either side of the center of the protractor (p). The bars holding these electrodes can be moved alongside each other; the transverse distance is also variable, therefore providing a great variety of needle positions. For more details the reader is referred to our forthcoming monograph.[1]




FIGS. 1 and 2. (See text for description.)

Stereoencephalotomy has been carried out in mental disorders (56 cases), intractable pain (20 cases), petit mal (5 cases) and extrapyramidal disorders (6 cases).

## REFERENCES

1. SPIEGEL, E. A., and WYCIS, H. T. Stereoencephalotomy. *New York: Grune & Stratton*, 1951. (In press)
2. SPIEGEL, E. A., WYCIS, H. T., MARKS, M., and LEE, A. J. Stereotaxic apparatus for operations on the human brain. *Science*, 1947, *106*: 349–350.
3. WYCIS, H. T., and SPIEGEL, E. A. Thalamotomy and mesencephalothalamotomy: neurosurgical aspects (including treatment of pain). *N.Y. St. J. Med.*, 1949, *49*, pt. 2: 2275–2277.

# TRANSLUCENT MODEL OF THE CEREBRAL VENTRICULAR SYSTEM

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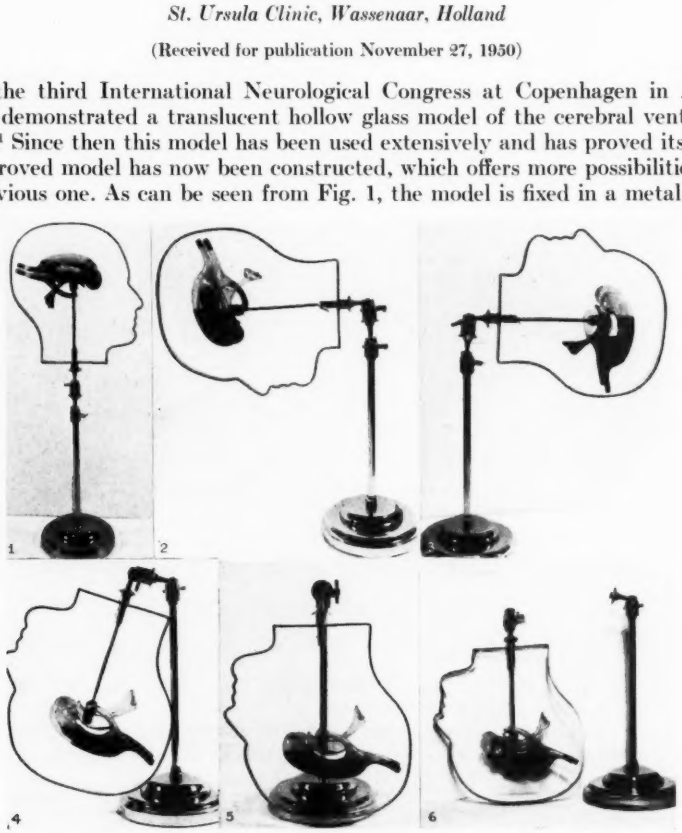
(Received for publication November 27, 1950)

At the third International Neurological Congress at Copenhagen in August 1939, I demonstrated a translucent hollow glass model of the cerebral ventricular system.[1] Since then this model has been used extensively and has proved its value. An improved model has now been constructed, which offers more possibilities than the previous one. As can be seen from Fig. 1, the model is fixed in a metal frame,




FIGS. 1–6. Translucent model of cerebral ventricular system (1/2 of original size). For the sake of contrast in reproduction, the fluid (alcohol 96 per cent) has been coloured with transparent black water-colour.

which outlines the contours of the head. The ventricles take up their normal place in the head. It can be filled partly with air, partly with fluid; the relation of these two can be varied at will. The head-frame can be moved freely in all directions because it is mounted on top of a standard. The style of this standard contains two socket-joints, which allow for every required movement and position; some of the many positions are shown in Figs. 2, 3, 4 and 5. The subdivisions can be taken apart (Fig. 6).

* The glass-models are constructed in the glass-works of Mr. H. Daudey at Haarlem, and can be ordered at Fa. Halgimex, Postbus 22, Haarlem, Holland.

Such a model has two main purposes: (1) It shows how the air and the fluid are distributed inside the ventricles in different positions of the head. It is of great value in studying the movements or succession of movements by which special parts of the system, such as 3rd or 4th ventricle and the temporal horn, can be filled most completely. (2) It shows how pictures of parts of the ventricular system can differ, depending upon the amount of air. If the amount is small it is much more difficult to fill the various parts; and one can see easily how the picture of the same part, f.i. the anterior horn, in the same position of the head varies considerably with different amounts of air. This is a great advantage of the model and has made it possible to read ventriculograms in cases with partial filling much more accurately. It certainly has avoided misleading and faulty conclusions, sometimes even unnecessary or inaccurate operations.

The only drawback to the model is that its walls are rigid. Pathological conditions therefore cannot be reproduced. But this seldom belongs to the possibilities of any model. It is, however, the study of the normal anatomical and physiological processes, closely imitating what happens in vivo, that has proved so often its considerable value in judging the findings in pathological processes.

The model is of direct importance to neurologists, neurosurgeons, and neuroradiologists, who can use it with great benefit during ventriculography.* But also for teaching purposes it has superior advantages; much better than lengthy theoretical explanations it offers to the students in a short time a vivid and accurate impression of the anatomical structure and of what is going on inside the ventricles during ventriculography.

I wish to express my sincere gratitude to Prof. Dr. J. Dankmeijer, head of the Anatomical Department of the University of Leyden, for his help in preparing the pictures, which have been made by his scientific photographer, Mr. H. F. Premsela, and for his kind permission to use these photographs for this article.

## REFERENCE

1. DE VET, A. C. Demonstration of a translucent model of the ventricular system. *C.R. III Congr. Neurol. Int.*, 1939, p. 750.

## NOTICES

### AMERICAN BOARD OF NEUROLOGICAL SURGERY

The following specialists were certified at a meeting of the American Board of Neurological Surgery in Chicago, Illinois, May 7 and 8, 1951.

ANDLER, MAXWELL M., JR. 405 North Bedford Drive, Beverly Hills, Calif.
BARRINGER, FLOYD S. 427 East Monroe St., Springfield, Ill.
BOOTH, GEORGE T. 1056 Secor Hotel Bldg., Toledo 4, Ohio
BROUGHAM, MILTON F. 412 Beacon St., Boston, Mass.
CHAMBERS, WILLIAM R. 706 Odd Fellows Bldg., South Bend 1, Ind.
COBB, CULLY A., JR. Vanderbilt University Hospital, Nashville 4, Tenn.
CURE, CHARLES W. 914 Hume Mansur Bldg., Indianapolis 4, Ind.
DESAUSSURE, RICHARD L., JR. 525 Physicians & Surgeons Bldg., Memphis 3, Tenn.
DUEKER, HOWARD W. 10220 Riverside Drive, North Hollywood, Calif.
GANG, KENNETH M. 62 Waller Ave., White Plains, N. Y.; 994 Fifth Ave., New York 28, N. Y.
GORDY, PHILIP D. 606 West 10th St., Wilmington, Del.
GREENWOOD, ROBERT C. Letterman Army Hospital, San Francisco, Calif.
HAWKINS, GEORGE L., JR. 607 North Grand Blvd., St. Louis, Mo.
HAWKINS, RALPH 571 Hamilton Ave., Palo Alto, Calif.
HAYNES, WALTER G. 811 South 20th St., Birmingham 5, Ala.
HOPPLE, THERON L. 1056 Secor Hotel Bldg., Toledo 4, Ohio
JONES, J. RANDOLPH 1627 Medical Arts Bldg., Houston 2, Texas
LEVIN, JULES D. 161 West Wisconsin Ave., Milwaukee 3, Wis.
OBERHILL, H. R. 25 East Washington St., Chicago 2, Ill.
PITTS, WILLIAM R. Doctors Bldg., Kings Drive, Charlotte 7, N. C.
POWELL, CHESTER B. 60 South Fourth East, Salt Lake City, Utah
RANSOHOFF, JOSEPH 710 West 168th St., New York 32, N. Y.
REVILLA, ANTONIO GONZALEZ P.O. Box 1392, Panama City, Republic of Panama
STELLAR, STANLEY 180 East 64th St., New York 21, N. Y.
SWEENEY, DONALD B. 2205 Highland Ave., Birmingham, Ala.
WEIFORD, EDWARD C. 1000 Professional Bldg., Kansas City 6, Mo.

### AMERICAN ACADEMY OF NEUROLOGY

At the meeting of the American Academy of Neurology at Virginia Beach on April 11 and 12, 1951, the following officers were elected for 1951–52. President, Dr. Pearce Bailey, Washington, D. C.; President Elect, Dr. Howard Fabing, Cincinnati; Vice-President, Dr. Walter Klingman, Charlottesville; Treasurer, Dr. Joe Brown, Minneapolis; Secretary, Dr. Francis M. Forster, Washington, D. C.

The next meeting will be in Louisville, Kentucky at the Brown Hotel on April 24 and 25. Courses will be given in neuropathology, neuroroentgenography and electroencephalography.

### ASSOCIATION FOR RESEARCH IN NERVOUS AND MENTAL DISEASE

The Annual Meeting of the Association for Research in Nervous and Mental Disease will be held on December 14 and 15, 1951 at the Roosevelt Hotel, New York City. The subject of the meeting will be "Treatment in Psychiatry."

### HARVEY CUSHING SOCIETY

The 19th meeting of the Harvey Cushing Society was held in Hollywood, Florida on April 26, 27 and 28, 1951.

At the annual dinner on Friday, Dr. W. Edward Chamberlain delivered the Presidential Address, "Some technical problems in cerebral angiography." A special ceremony of the evening was the presentation of a bronze plaque to Charles C Thomas, Publisher by Dr. A. Earl Walker, Chairman of the Program Committee, with the inscription: "In recognition of his outstanding contributions as a publisher, especially in the field of Neurological Surgery, the Harvey Cushing Society presents this plaque to Charles C Thomas, April 27, 1951."

The following officers were elected for the 1951–52 term: Dr. Paul C. Bucy, Chicago, President; Dr. Frederic Schreiber, Detroit, Vice-President. Dr. Louise Eisenhardt, New Haven, is Secretary-Treasurer. The next meeting of the Society will be in Victoria, B. C. on June 5, 6 and 7, 1952.

### NEUROSURGICAL SOCIETY OF AMERICA

The Neurosurgical Society of America will hold its 4th Annual Meeting at Sun Valley, Idaho, September 12–14, 1951. The program includes panel discussions on hypertension and brain tumor therapy, and a neuropathological conference. Dr. George Roulhac, St. Louis, is President and Dr. C. D. Hawkes, 22 North Manassas, Memphis, is Secretary.

### SCANDINAVIAN NEUROSURGICAL SOCIETY

The 7th meeting of the Scandinavian Neurosurgical Society will take place in Copenhagen, Denmark, September 1–3, 1951. Members of American and other European neurosurgical societies are cordially invited to attend. The main subject of the meeting will be "The Pathology and Treatment of Head Injuries." Information is obtainable from the Secretary, Dr. Olof Sjöqvist, Södersjukhuset, Stockholm, Sweden or from Dr. Bendt Broager, Rigshospitalets Neurokir. Afd. Tagensvej 18, Copenhagen, Denmark.

# BRAIN TUMORS SIMULATING MENINGITIS

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(Received for publication January 26, 1951)

With the advent of chemotherapy, the treatment of meningitis has, for the most part, become quite stereotyped. Many patients presenting the most elementary symptoms of meningeal involvement are subjected to intensive doses of the various chemotherapeutic agents and in many cases very little further attempt is made to trace the detailed etiology of the meningeal involvement. In those cases of meningitis due to bacterial organisms this type of procedure may be successful, but because many causes of meningeal irritation are encountered in the practice of medicine that are not infectious in origin, a word of caution must be inserted as to such a therapeutic procedure. Failure to investigate a patient thoroughly at the onset for the specific cause of the meningeal involvement may well result in the neglect of a neurological condition that obviously cannot respond to chemotherapy. This should particularly be kept in mind when the patient fails to respond in an adequate fashion to the therapeutic procedures instituted. Such an unusual course of the illness should make the doctor suspect that the cause of the meningitis might be atypical and that further detailed investigation is indicated. The following 3 cases are reported to emphasize the above facts. In all 3 cases the patients suffered from brain tumors which presented themselves as a meningitis.

*Case 1.* W.E., U.H. No. 747709.

*Summary.* Dermoid cyst involving inferior portions of both frontal lobes, with a long history of sinusitis. Onset of acute illness upon blowing of nose, with severe meningeal reaction, fever, leucocytosis and spinal fluid pleocytosis. Fulminating increased intracranial pressure after encephalography. Partial removal and evacuation of an intracerebral cyst. Recovery.

*History of Illness.* A white male of 27 years was admitted to the Student Health Service in March 1950 with complaints of severe headache which had come on suddenly after he had blown his nose. Initially the headache was felt all over the head, but soon became localized to the frontal areas with no predilection for one side or the other. The patient felt very ill and retired to bed, remaining there without abatement of his complaints until the next morning when he reported to one of his classes in order to take an examination. Following this he returned to bed. Shortly thereafter he became nauseated, vomited and felt that he had a fever. Forty-eight hours after the onset, he was admitted to the hospital.

*Past History.* Although the patient had suffered from sinusitis for many years, he was first treated for that disability in 1945 while in the service. During Naval training he had a high fever with a headache and rash which was diagnosed as scarlet fever. During convalescence migratory joint pains and a cardiac murmur developed

with another episode of fever and headache. A diagnosis of rheumatic fever was made. Under salicylates he made a slow recovery but remained in the hospital because of the persistence of headache, joint pains and increased sedimentation rate. The headache was felt to be sinusal in origin and a Luc-Caldwell procedure was performed on the left side.

Nine months later he was given sea duty and during that period the sinuses were drained several times. Upon discharge he returned to school where he played 3 years of intercollegiate football and 1 year of professional football. During his athletic career he was knocked unconscious on 2 or 3 occasions, and he recalled a similar episode at the age of 13.

*Examination.* The patient appeared ill, complained of pain on movements of the eyes and photophobia, and had a temperature of 100.6°F. Cardiovascular, respiratory and gastro-intestinal systems were within normal limits. Positive neurological findings were: nuchal rigidity, engorgement of the retinal veins without papilloedema, and areflexia.

*Laboratory Data.* WBC 12,900: 92 per cent polymorphonuclear leucocytes, 7 per cent lymphocytes and 1 per cent monocytes. Sedimentation rate was elevated. Blood chemistries and urines were normal. CSF pressure was 26 mm. of mercury; the fluid showed 1,744 WBC/c.mm.: 97 per cent polymorphonuclear cells, and 3 per cent mononuclear cells. There were 76 RBC. CSF protein was 41 mg. per cent; sugar 56 mg. per cent; and chlorides 127 milli equivalents/1. Smear of the fluid showed no organisms and culture was sterile.

*Diagnosis.* In view of the sudden onset of the symptomatology, the physical findings and the antecedent history of sinusitis it was thought that the patient had a meningitis probably secondary to a ruptured epidural abscess.

*Course.* The patient was treated with antibiotics and sulfa compounds. He received intravenous feedings and required demerol for relief of his headache. Under this regime he responded quite well and the temperature slowly returned to normal. CSF pressure on the 3rd hospital day was 20 mm. of mercury; the fluid showed 220 cells, of which 90 per cent were polymorphonuclear leucocytes. Attempts to culture organisms from the CSF were unsuccessful. Despite general improvement his temperature continued to spike nearly every day and he occasionally complained of chills.

On the 27th hospital day pneumoencephalography was done; 25 cc. of air were introduced into the spinal canal and an equal amount of CSF was withdrawn. During this procedure the patient had one convulsion. Roentgenograms showed a small pocket of air in the left frontal lobe anterior to the lateral ventricle, but no communication with the lateral ventricles was visible. Following this procedure the patient became worse. Nausea, vomiting and severe headache were persistent and in the course of 24 to 36 hours papilloedema appeared bilaterally, associated with paresis and hyperactive reflexes on the right side. In view of this unsatisfactory turn of events immediate surgical intervention was carried out. The pre-operative diagnosis was probable left frontal lobe abscess.

*1st Operation.* Under general anaesthesia a trephine opening was made over the left frontal eminence and a brain needle inserted to a depth of 4 cm., where a cyst was encountered, from which sebaceous material with hair was evacuated.

*Course.* It was expected that the patient would be relieved by this evacuation until a definitive operation could be performed at an elected time. However, during the next 24 to 36 hours he showed evidence of increasing intracranial pressure

with the development of bilateral abducens paralysis, an increase in papilloedema and retinal hemorrhages.

*2nd Operation.* Under intratracheal anaesthesia a left transfrontal craniotomy was performed. Decompression of the cyst by another evacuation through a brain cannula was necessary prior to reflection of the bone because of extreme intracranial pressure with herniation of cerebral tissue through the trephine opening previously made. The anterior portion of the left frontal lobe and an anterior projection of the cyst were amputated. The remainder of the cyst extended posteriorly in the frontal lobe across the midline behind the falx and expanded into the right frontal lobe (Fig. 1). The bulk of the cyst was in and near the midline, situated above the optic

FIG. 1 (*left*). Composite drawing showing midline position of dermoid cyst in Case 1. In the interior of the cyst a small dermoid tuft in the floor of the left frontal projection is shown. The optic chiasm can be seen underlying the cyst.

FIG. 2 (*right*). Photograph of dermoid tuft removed from cyst wall. Hair is readily observed.

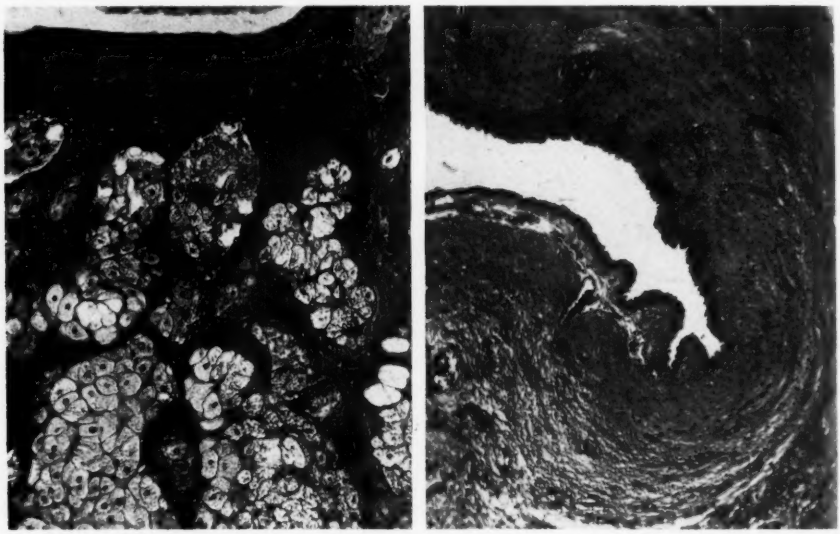
nerves, chiasm and pituitary gland and beneath the hypothalamus and 3rd ventricle. An attempt was made to dissect out the wall of the cyst and this was partially successful but it soon became evident that a complete removal would be impossible. A small raised plaque containing hair was encountered in the cyst wall (Fig. 2).

*Microscopic Diagnosis.* Dermoid cyst (Figs. 3 and 4).

*Postoperative Course.* The patient's course was complicated with convulsions which were controlled with anticonvulsant drugs. He made steady satisfactory progress despite mild diabetes insipidus which subsequently subsided. It was noted that he was blind in the right eye. He had a mild paresis of the right leg but was able to walk with the aid of a cane. He was discharged on the 25th day after operation and has returned to school.

*Discussion.* This case of a large dermoid cyst of the frontal lobes presented itself as a meningitis. It is well known that the contents of dermoid and epidermoid cysts of the brain are very irritating to the ependymal lining. In this case it was thought that the acute exacerbation of symptoms after

encephalography unrelieved by evacuation of the cyst was due to ependymitis with obstruction of the aqueduct. Such an obstruction of the aqueduct resulting from the irritating effect of the contents of a dermoid cyst was found at postmortem examination in a case reported by Miller.[16] Had the cerebrospinal fluid been examined by a physician instead of a laboratory technician the significance of the fat and epithelial cells would have been appreciated and an early diagnosis made, since such elements were present in quantity but not recorded.



FIGS. 3 and 4. Case 1. Photomicrographs showing (*left*) cyst wall containing dermal and epidermal elements, and (*right*) projection of cyst into cerebral tissue.

*Case 2.* E.C., U.H. No. 812733.

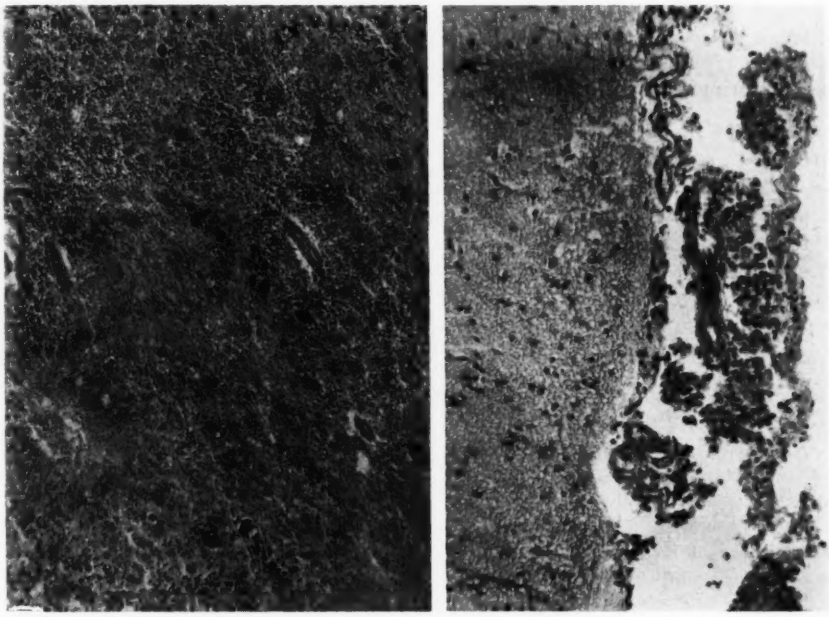
*Summary.* Semicomatose patient with marked spinal fluid pleocytosis and signs suggestive of meningitis. Abnormal course prompted further investigation, which revealed brain tumor of frontal lobes. Diagnosis: glioblastoma multiforme.

*History of Illness.* A female of 69 years was admitted to the University Hospital in a semicomatose condition in November, 1949. She had first complained of severe unlocalized headaches 5 months previously. Two months before admission she had had "flu" which was unresponsive to the usual household remedies. Upon signs of confusion and disorientation she was entered in a local hospital with a diagnosis of atypical pneumonia. Penicillin therapy was instituted with considerable improvement and against advice the patient left the hospital, only to be readmitted 1 week later in a semicomatose condition. At this time there was marked nuchal rigidity with bilaterally fixed and dilated pupils, a right hemiparesis with hyperactive reflexes and ankle clonus. The patient was febrile. The blood urea nitrogen was 40 mg. per cent. There was a leucocytosis of 13,400 cells, of which 85 per cent were polymorphonuclear leucocytes. CSF showed 122 WBC: 73 per cent were polymorphonuclear leucocytes. Three days later the CSF showed 560 WBC: 96 per cent were

polymorphonuclear leucocytes. At this point she was transferred to the University Hospital.

*Examination.* The patient was unable to cooperate, muttered unintelligently but responded reflexly to noxious stimulation. Temperature was 99.6°F. and pulse 90. Positive neurological findings were: marked nuchal rigidity, left hemiparesis with a positive Babinski reflex, ankle clonus and a grasping reflex on the right. There were no cranial nerve abnormalities.

*Past History.* With the exception of a nephrectomy at the age of 17 for renal tuberculosis the past history was not contributory.



FIGS. 5 and 6. Case 2. Photomicrographs of (*left*) glioblastoma, showing pleomorphism, giant cells and tissue necrosis and (*right*) meninges near tumor showing inflammatory cells in the subarachnoid space.

*Laboratory Data.* Hb. 15.2 gm. WBC 8,250 with a normal differential. Blood urea nitrogen 13 mg. per cent, $CO_2$ combining power 24, chlorides 104 milli equivalents/l. and serum protein 6.1 gm. Roentgenograms of the chest were normal except for an insignificant congenital rib anomaly.

CSF pressure was 200 mm. of water. WBC was 154, of which 123 were polymorphonuclear leucocytes. CSF protein, 154 mg. per cent. The culture was sterile.

*Diagnosis.* On the basis of the foregoing a diagnosis of tuberculous meningitis was made and treatment instituted accordingly.

*Course.* The patient continued in a semicomatose state throughout her hospitalization. Aureomycin, streptomycin and penicillin produced no significant change. In view of the lack of change under chemotherapy and the localization of findings to the right frontal area, further investigation was felt necessary. Angiography showed no alteration in the vascular pattern. Pneumoencephalography showed

definite evidence of a large mass in the right lateral ventricle. No air entered the left lateral ventricle. In an attempt to obtain more satisfactory visualization of the ventricular system, ventriculography was done which showed a large mass involving the corpus callosum, septum pellucidum and projecting from the roof of both lateral ventricles, which were dilated.

*Operation.* Upon exposure of the right lateral ventricle the tumor was observed involving the ventricular wall and projecting into the ventricular cavity. A partial removal was effected.

*Course.* The patient remained comatose and expired 1 week postoperatively.

*Autopsy Report.* There was a large, diffuse, poorly circumscribed, necrotic and hemorrhagic tumor extending into the frontal and parietal lobes bilaterally with destruction of the corpus callosum, septum pellucidum and obliteration of the 3rd ventricle.

*Microscopic Diagnosis.* Glioblastoma multiforme (Fig. 5).

*Discussion.* The onset of signs of meningeal irritation and the high proportion of polymorphonuclear leucocytes in the spinal fluid suggested a primary meningitis. The failure to respond to antibiotics and the abnormal course prompted further investigation which led to the proper diagnosis. The cause of the meningeal reaction was felt to be due to both tumor necrosis and the products of hemoglobin breakdown. Myelin destruction may also have contributed to this response. Fig. 6 shows the meningeal reaction in the vicinity of the tumor.

*Case 3.* E.R., V.A. 80512.

*Summary.* Cerebral varix involving the 3rd ventricle, producing clinical and laboratory signs of meningitis. Fatal outcome.

*History of Illness.* A white male of 23 years was admitted to the hospital with complaints of occipital headache and stiff neck accompanied by nausea and vomiting. The onset was dated 1 week previously. Since the age of 13, the patient had suffered periodically from headaches confined to the left side of his head; symptomatic relief had been obtained from large doses of sodium amytal. The pain on admission was not related or similar to his previous headaches. He also complained of pain in the posterior neck muscles, and staggering had been noted by relatives during the last 2 days.

*Past History.* With the exception of the headaches previously described the past history was noncontributory.

*Examination.* The patient was acutely ill, restless, drowsy, slightly febrile and complained bitterly of headache. The only abnormal neurological findings were nuchal rigidity and an equivocal Babinski reflex on the right side.

*Laboratory Data.* WBC 17,000: 81 per cent polymorphonuclear leucocytes, and 19 per cent lymphocytes. The CSF was under a pressure of 400 mm. of water and showed a pleocytosis of 694 WBC: 89 per cent polymorphonuclear leucocytes and 11 per cent lymphocytes. A smear of the CSF showed gram positive cocci resembling pneumococci. CSF sugar was 73 mg. per cent, protein 38 mg. per cent, and chlorides 102 milli equivalents/1. Urinalysis, blood serology and roentgenograms of chest and skull were normal.

*Diagnosis.* On the basis of the clinical findings substantiated by the presence of organisms in the spinal fluid a diagnosis of pneumococcic meningitis was made.

*Course.* The patient was treated with large doses of penicillin intramuscularly nd intrathecally. Daily spinal punctures were performed, each of which showed blood-tinged fluid under pressures ranging from 400 mm.–600 mm. of water. No rganisms were grown and the gram positive cocci first observed were never seen on ubsequent smears. No additional neurological findings appeared with the exception f papilloedema of 1 D. which subsided after a period of 3 days. Shortly thereafter, owever, bilateral choked discs of 3–4 D. developed with retinal hemorrhages. entriculography showed bilateral symmetrical hydrocephalus. Two days following his procedure the patient suddenly became cyanotic with shallow gasping irregular

FIG. 7. Case 3. Horizontal section of brain showing large central varix, displaced 3rd ventricle and dilated lateral ventricles.

respirations and passed into a semicomatose condition which terminated fatally. A presumptive diagnosis of tumor of the 3rd ventricle was made.

*Postmortem Report.* Horizontal sections of brain showed dilatation of the lateral ventricles. Immediately posterior to the optic chiasm and displacing the 3rd ventricle was a large subependymal hemorrhagic mass 3 cm. in diameter. Fig. 7 shows the gross appearance of the lesion.

*Microscopic Diagnosis.* Cerebral varix.

*Discussion of Case.* The meningeal reaction and spinal fluid pleocytosis are assumed to have been due to the breakdown products of hemoglobin. Hydrocephalus was the cause of death. A very similar case was reported by Merwarth and Freiman,[15] of a child who died at the age of 4 months of communicating type of hydrocephalus due to intraventricular hemorrhage from a small angioma in the thalamus.

## DISCUSSION

It is known that meningeal irritation with associated meningitis can be caused by numerous agents. Acute demyelinating diseases may elicit intense lymphocytic, polymorphonuclear and plasma cell reactions. The disintegration products of nerve tissue have been accepted as a cause for such reactions. Bender[5] injected lipoid fractions derived from myelin into the subarachnoid space and obtained a polymorphonuclear response in the cerebrospinal fluid. Cholesterin was found to be more potent in activating such a response than cerebrosides. It is now well appreciated that the CSF may contain large numbers of polymorphonuclear cells following operations upon cholesteatomas or cholesterin-containing cysts of the brain. The rapid disintegration of myelin due to embolism or thrombosis of a vessel is followed by a polymorphonuclear response in the meninges. Such a reaction was experimentally reproduced by Cone and Barrera,[9] who blocked the cerebral vessels with aseptic emboli.

Bagley[1] reported both clinical and experimental evidence of chronic meningitis in the dog following repeated injections of blood into the subarachnoid space. Aseptic meningitis following subarachnoid hemorrhage has been reported by Lamb,[14] Strauss, Globus and Ginsburg,[21] Bagley,[2] Cookson,[10] Sands,[19] Dandy,[11] Richardson and Hyland,[18] Collier,[8] and Bramwell.[6] Mallory[7] reported a case of intracranial varices in which symptoms of meningeal irritation followed each episode of rupture. Spurling[20] described aseptic meningitis following craniocerebral injuries. Bedford[4] showed that isotonic sodium chloride injected into the cisterna magna caused a pleocytosis. Jackson,[13] in a comparative study of the reaction of blood and its breakdown products in the subarachnoid space, has shown that bilirubin is probably the specific agent in blood that is responsible for the meningeal reaction.

Although meningitis occurring as a result of bacterial invasion, viral invasion and demyelinating processes is frequently sought for in the routine investigation, the fact that a similar process may be caused by brain tumors is generally not appreciated. Cerebral tumors as a rule produce no change in the cell count of the cerebrospinal fluid. When, however, intracranial tumor is associated with large numbers of cells in the CSF, necrosis of the tumor or myelin destruction in the perineoplastic area is presumed to be the cause. When gliomas situated near the ventricles undergo softening the CSF may contain a great excess of polymorphonuclear cells. Pennybacker,[17] speaking of the spinal fluid, has stated that "increase in the protein content is a very common finding in cases of intracranial neoplasms of all sorts and the cell count may be raised with or without an increase in the protein content. Some cases of degenerating and necrotic gliomata situated near the ventricular system or the subarachnoid space may show a marked pleocytosis contributed to by polymorphs as well as by lymphocytes." Bailey[3] states that ordinarily there is no increase in the cell count of the CSF in brain tumor.

An analysis of a report by Henderson and de Gutiérrez-Mahoney[12] on the

CSF in brain tumor shows the greater frequency of spinal fluid pleocytosis in glioblastoma multiforme. Of 43 cases of glioblastoma multiforme, 13 exhibited pleocytosis ranging from 14 to 70 cells, of which large numbers were polymorphonuclear. In all such cases the ventricular walls were infiltrated with tumor. Metastatic tumors were not infrequently accompanied by CSF pleocytosis, whereas other types of cerebral tumor were associated with an increase of only 1 or 2 cells over the normal value.

The clinical courses of the common varieties of meningitis are well known. Any type of meningitis with an abnormal course should be viewed with suspicion and further investigative procedures undertaken in order to determine the etiology. Pneumoencephalography, ventriculography and arteriography are measures available to enable the clinician to arrive at the correct diagnosis. It is equally important to be aware of the fact that meningitis can develop during the course of a brain tumor.

## SUMMARY

Three cases of brain tumor of varied pathology presenting as meningitis have been reported.

Intracranial neoplasms are to be accorded an important place in the etiology of meningitis.

Any meningitis of an abnormal course should be viewed with suspicion and further studies done to determine the etiology.

## REFERENCES

1. Bagley, C., Jr. Blood in the cerebrospinal fluid. Resultant functional and organic alterations in the central nervous system. A. Experimental data. *Arch. Surg., Chicago,* 1928, *17:* 18–38. B. Clinical data. *Ibid.,* 39–81.
2. Bagley, C., Jr. Spontaneous cerebral hemorrhage. Discussion of four types, with surgical considerations. *Arch. Neurol. Psychiat., Chicago,* 1932, *27:* 1133–1174.
3. Bailey, P. Intracranial tumors. *Springfield, Ill.: Charles C Thomas,* 1948, 2nd ed., xxiv, 478 pp.
4. Bedford, T. H. B. The effect of introduction of isotonic sodium chloride solution into the cisterna magna of the dog on the cell content of the cerebrospinal fluid. *J. Physiol.,* 1946, *104:* 299–304.
5. Bender, L. Experimental production of gliosis. I. Effects on the nervous system of the rabbit of intravenous and intraspinal injections of cholesterol emulsion. *Amer. J. Path.,* 1925, *1:* 657–665.
6. Bramwell, E. Upon (1) leaking aneurysm of the cerebral arteries as a cause of third nerve paralysis, with special reference to two cases in which the diagnosis was confirmed by arterial radiography; (2) a note upon the aetiology of recurrent and periodic ocular palsy and ophthalmoplegic migraine. *Trans. ophthal. Soc. U.K.,* 1934, *54:* 205–221.
7. Case Records of the Massachusetts General Hospital. Case 24121. *New Engl. J. Med.,* 1938, *218:* 529–531.
8. Collier, J. Observations on cerebral haemorrhage due to causes other than arteriosclerosis. *Brit. med. J.,* 1931, *2:* 519–521.
9. Cone, W., and Barrera, S. E. The brain and the cerebrospinal fluid in acute aseptic cerebral embolism. An experimental and pathologic study. *Arch. Neurol. Psychiat., Chicago,* 1931, *25:* 523–547.
10. Cookson, H. Spontaneous subarachnoid haemorrhage. With report of eight cases. *Brit. med. J.,* 1933, *1:* 555–558.
11. Dandy, W. E. Intracranial arterial aneurysms. *Ithaca, N. Y.: Comstock Publishing Co., Inc.,* 1944, viii, 147 pp.
12. Henderson, W. R., and de Gutiérrez-Mahoney, C. G. Cerebrospinal fluid in 302 cases of intracranial tumour, abscess, and subdural haematoma. *Brit. med. J.,* 1950, *1:* 1461–1465.
13. Jackson, I. J. Aseptic hemogenic meningitis. An experimental study of aseptic meningeal reactions due to blood and its breakdown products. *Arch. Neurol., Psychiat., Chicago,* 1949, *62:* 572–589.
14. Lamb, F. H. Spontaneous meningeal hemorrhage. *J. Lab. clin. Med.,* 1930. *15:* 531–537.

15. Merwarth, H. R., and Freiman, I. S. Hydrocephalus following subarachnoid hemorrhage. Report of a case with pathologic study. *Brooklyn Hosp. J.*, 1939, *1:* 149–157.
16. Miller, D. Case report: dermoid cyst of the frontal lobe with intraventricular rupture. *J. Neurol. Neurosurg. Psychiat.*, 1950, n.s. *13:* 63–65.
17. Pennybacker, J. Discussion on diagnosis and treatment of cerebral abscess. *Proc. roy. Soc. Med.*, 1945, *38:* 431–438.
18. Richardson, J. C., and Hyland, H. H. Intracranial aneurysms. A clinical and pathological study of subarachnoid and intracerebral haemorrhage caused by berry aneurysms. *Medicine, Baltimore*, 1941, *20:* 1–83.
19. Sands, I. J. Subarachnoid hemorrhage. A study of 83 cases. *Trans. Amer. neurol. Ass.*, 1938, 144–147.
20. Spurling, R. G. Craniocerebral trauma. In: *Surgical treatment of the nervous system.* F. W. Bancroft and C. Pilcher, Ed. Philadelphia: J. B. Lippincott Co., 1946, xvii, 534 pp. (see pp. 27–62).
21. Strauss, I., Globus, J. H., and Ginsburg, S. W. Spontaneous subarachnoid hemorrhage. Its relation to aneurysms of cerebral blood vessels. *Arch. Neurol. Psychiat., Chicago*, 1932, *27:* 1080–1130.

# ELECTROMYOGRAPHIC OBSERVATIONS ON THE POSTOPERATIVE DISC PATIENT*

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ELECTROMYOGRAPHIC studies of the sacrospinalis muscles in patients complaining of low back pain following the operative removal of a herniated intervertebral disc in the lumbar region have yielded evidence of segmental denervation. The present report comprises 18 cases, including 6 of severe lower back pain associated with sacrospinalis denervation. An attempt is made to correlate the denervation with the detailed anatomy of the posterior division of the lumbar nerve and to offer a possible explanation of the postoperative back pain on an anatomical basis.

In 1944 Weddell, Feinstein and Pattle[3] published their observations on the electrical activity of voluntary muscle in man under normal and pathological conditions. They found evidences of denervation in the sacrospinalis muscles following laminectomy for prolapsed intervertebral disc and other conditions, i.e., the presence of fibrillation potentials, complex motor unit potentials, and diminution or absence of motor unit potentials as recorded in the electromyograph.

Their observations were based upon a study of some 25 cases and they supposed that the denervation was due to ischemic nerve block following the use of self-retaining retractors in the wound. They particularly called attention to the fact that this area of denervation was from 1 to 2 cm. lateral to the incision and that elsewhere in the sacrospinalis muscles there were sustained motor unit potentials and an absence of fibrillations. In another series of 25 cases, in which a unilateral laminectomy was performed, they observed that the denervation was present only on the operated side. Finally, in 1 case of laminectomy for prolapsed intervertebral disc in which manual retractors were used and the muscles submitted to minimal traction during the operation, they stated that 12 days after operation there was no evidence of denervation 2 cm. or more from the midline scar. Within 3 months, motor unit activity had returned to normal to within approximately 1 cm. of the scar. A little more medially fibrillation potentials were recorded, even up to a period of 1 year.

The writer has come to feel that denervation is an important factor in the syndrome of back pain in the postoperative disc patient.

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## METHOD AND RESULTS

Electromyographic studies were performed on the sacrospinalis muscles in 18 patients who had complained of low back pain during the postoperative period following removal of protruded intervertebral disc.

Observations were made with the electromyograph using both the loud speaker and the oscilloscope method, with the coaxial needle type of electrode.

Six of the 18 patients demonstrated reduced motor unit action potentials or absence of the same, and the presence of marked fibrillations. These findings were recorded in the sacrospinalis muscle group in an area lateral to the site of operation, extending approximately 5 cm. lateral to the operative wound and 5–6 cm. in a longitudinal direction. All patients studied had had unilateral laminectomies, and in all cases normal electromyographic recordings were observed on the side that had not been operated upon. In the 6 cases in which denervation was demonstrated, it is interesting to note that all of these patients were complaining of diffuse low back pain of moderate severity. The pain was of a different type than that experienced prior to surgery, and had its onset 15 to 30 days postoperatively. In the remaining 12 cases only very occasional fibrillations were present and active motor unit action potentials were observed throughout the area. Furthermore, these 12 patients had no pain at the time of the study.

The maximum duration of postoperative denervation was 293 days and the minimum 97, with an average of 183 days. Attempts to recapitulate the periods of postoperative pain for the group who at the time of examination had normal electromyograms resulted as follows: Three patients stated they had had some back pain for a period of 60 days postoperatively; 1 had back pain for 95 days; 1 had back pain for 120 days; and 1 had back pain for 148 days.

## CASE REPORTS

*Case 1.* J.B., No. 1456. Diagnosis: Herniated intervertebral disc, L4. Operation: Partial hemilaminectomy with removal of herniated disc. Course: Severe pain was present 97 days after operation. Electromyographic study demonstrated absent motor potentials and presence of continuous fibrillations. At 148 days, when there was marked subjective improvement in the pain, repeated electromyogram demonstrated good active motor unit action potentials and very few fibrillations.

*Case 2.* E.P., No. 1340. Diagnosis: Herniated intervertebral disc, lumbosacral joint. Operation: Partial hemilaminectomy with removal of herniated disc. Course: At 205 days, electromyographic study demonstrated the presence of denervation. At 230 days, when the patient was showing subjective improvement, there was a parallel improvement in the electromyogram, with increasingly active motor unit action potentials and marked decrease in the number of fibrillations.

*Case 3.* B.B. No. 1466. Diagnosis: Herniated intervertebral disc, lumbosacral joint. Operation: Partial hemilaminectomy with removal of herniated disc. Course

At 24 days, when this man was complaining of severe pain in the back and also severe pain in the groin, an electromyogram showed no evidence of motor unit action potentials in the area studied and only very few fibrillations. On the 115th postoperative day, the patient stated that he had marked diminution of back pain and that the pain in the groin had disappeared. Electromyographic study demonstrated motor unit action potentials, though they were not particularly numerous, as well as the presence of fibrillations.

*Case 4.* J.C., No. 1289. Diagnosis: Herniated intervertebral disc, lumbosacral joint. Operation: Partial hemilaminectomy with removal of herniated disc. Course: Denervation and severe pain were present on the 232nd postoperative day. At 293 days there had been marked improvement in the back pain and electromyography revealed active motor unit potentials and a diminishing number of fibrillations.

## DISCUSSION

While this small number of cases does not present sufficient evidence for definite conclusions, it does indicate the possibilities for a quantitative method of evaluating the problem of postoperative back pain. Certainly there is some parallel to be drawn between the severity of denervation as observed in the electromyogram and the presence of severe postoperative low back pain.

Weddell, Feinstein and Pattle concluded that the denervation was due to a reversible ischemic block of the nerves and suggested that the use of manual retractors instead of the very popular self-retaining retractor would perhaps reduce the incidence of this finding. The writer feels that an ischemic block is the cause in certain of these cases, perhaps those in which there is an early return of function, with early loss of back pain and normal electromyogram.

However, attention should be called to the anatomy of the posterior primary division of the spinal nerve root. Even the slightest traction upon the nerve root, such as is so common in the type of buttonhole operation now popular, will cause a stretch injury to this posterior primary division and thereby impair the nerve supply to the contiguous portion of the sacrospinalis muscle, which receives a segmental nerve supply via this nerve. There exists a very intimate relationship of this posterior division with the transverse process of the vertebra—a relationship that will not allow traction without injury and one that is constant throughout the body. The nerve passes dorsally from the neural foramina in close contact with the bony roof of the canal and then turns 90° caudally over the transverse process before entering the overlying sacrospinalis muscle. In addition to supplying the muscle, both the medial and lateral branches of the posterior division of the lumbar and sacral nerves transmit cutaneous fibers. These fibers supply cutaneous areas over the lower back and buttock. Hence it may be postulated that, if a stretch injury has occurred, one may anticipate pain or hypersensitivity in the areas receiving sensory supply via these routes. This possible cause of pain should be considered in addition to the fact that pain may

be anticipated from ligamentous strain caused by loss of protective muscular power in the lower back as a result of sacrospinalis denervation.

I feel certain that with these points in mind during the performance of a disc operation we may well avoid this complication by being careful to prevent any traction on the spinal nerve root. Morbidity is remarkably decreased in the type of case in which the ruptured disc is quite evident, presenting immediately upon removal of the ligamentum flavum, so that no nerve root retraction is necessary. On the contrary, in cases in which the nerve root is scarred to the pathological disc and requires some traction and manipulation in order to release it and retract it medially, a marked increase in postoperative symptomatology may be expected.

## SUMMARY

Eighteen cases of postoperative back pain have been studied electromyographically, including 6 cases of sacrospinalis denervation associated with severe lower back pain.

Evidence of re-innervation of the previously denervated muscle groups has been observed at 148, 230, 115 and 293 days postoperatively.

In all cases the improvement or cessation of pain has paralleled the improvement in the electromyographic recordings—indicating a return of innervation to the involved muscle segments.

Attention has been called to the likelihood of a stretch injury of the posterior division of the spinal nerve root as a cause for this denervation.

The probability of some localized denervation on an ischemic block basis, caused by the use of self-retaining retractors, has been pointed out.

## REFERENCES

1. Pitkin, G. P. Conduction anesthesia. *Philadelphia: J. B. Lippincott Co.*, 1946, xii, 981 pp.
2. Shea, P. A., Woods, W. W., and Werden, D. H. Electromyography in diagnosis of nerve root compression syndrome. *Arch. Neurol. Psychiat., Chicago*, 1950, *64*: 93–104.
3. Weddell, G., Feinstein, B., and Pattle, R. E. The electrical activity of voluntary muscle in man under normal and pathological conditions. *Brain*, 1944, *67*: 178–257.

# POSTOPERATIVE SURVIVAL OF PATIENTS WITH INTRACRANIAL OLIGODENDROGLIOMA WITH SPECIAL REFERENCE TO RADICAL TUMOR REMOVAL

## A STUDY OF 26 PATIENTS

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When Bailey and Hiller[3] suggested in 1924 that certain gliomas were composed of oligodendrocytes, much interest was created concerning the existence of oligodendrogliomas as an entity. In 1926, Bailey and Cushing[2] set apart a group of brain tumors as oligodendrogliomas with histologic verification. Nine cases of such growths out of 254 classified tumors were reported by these authors. One of their patients survived 21 years after the onset of symptoms. Subsequent reports by other authors also suggested that this particular type of glioma was slow in growing and relatively benign. In order to evaluate further the postoperative survival period of patients harboring this tumor, it is our purpose to present the following 26 cases of verified oligodendrogliomas that have been seen at the Lahey Clinic from 1932 to 1949.

Oligodendrogliomas were characterized clinically by Bailey and Cushing as "slow-growing with the appearance of encapsulation, and unless they happen to produce focal and irritative lesions [they] may attain a large size before they make their presence known—so large a size that their removal is well nigh impossible." Pathologically, "these tumors have a pinkish color on fresh section. They also tend to show calcareous deposits often seen on x-ray films." According to Cushing,[7] "when fixed, stained and sectioned by ordinary methods the lesions have a characteristic and often unmistakable appearance, the compact mass of small cells with scanty clear cytoplasm having, as Bailey points out, some resemblance to the section of a woody plant."

In 1935 Elvidge, Penfield and Cone[10] utilized the terms oligodendroglioma and oligodendroblastoma because of differences in the cell types seen in tumors of this group, and Kernohan[12] in 1938 also thought that this differentiation microscopically was desirable.

Although Bailey and Cushing's[2] earlier observations revealed no mitoses in these tumors, further experience has shown that they are not always as innocent and slow in growth as they were thought to be. Abundant mitoses and metastases have been described by Martin,[14] by Bailey and Bucy[1] and

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by Eisenhardt.[9] Beck and Russell[4] reported 4 cases which showed metastases throughout the cerebrospinal pathway. Blumenfeld and Gardner[5] also reported a case of disseminated oligodendroglioma.

Martin[14] classified these tumors into (1) oligodendroglioma of the hemispheres and (2) oligodendroglioma of the midline. In 1939 a more detailed classification was made by Löwenberg and Waggoner.[13] These authors described (1) bilateral oligodendroglioma of the hemispheres, (2) unilateral oligodendroglioma of the hemispheres, (3) intraventricular oligodendrogliomas, (4) oligodendroglioma of the basal ganglions, (5) oligodendroglioma of the brain stem, (6) oligodendroglioma of the cerebellum and (7) oligodendroglioma of the spinal cord. As an example of the latter, Russell and Bucy[16] recently reported a case in which the initial symptoms were noted 14 years prior to operation.

In respect to the life history and postoperative survival periods of patients having intracranial oligodendrogliomas there are significant data from three recent articles, namely, the 25 cases analyzed by Shenkin, Grant and Drew[17] in 1947, the large series of 165 cases from the Mayo Clinic reported by Earnest, Kernohan and Craig[8] in 1950 and the series of 74 cases from Olivecrona's clinic reported by Reymond and Ringertz.[15] Previous to these publications, Bailey and Cushing had reported that 4 of their 9 patients were living 4 years or more following operation, and of the 8 patients of Elvidge, Penfield and Cone, 3 were living, the longest survival being 3 years.

Shenkin, Grant and Drew found that the average survival of their patients was a little less than 2 years, and these authors, as well as Elvidge, Penfield and Cone, thought that the length of postoperative survival was disproportionately shorter than the duration of preoperative symptoms. This feature was not substantiated in the report of Reymond and Ringertz as they found no correlation between length of symptoms and survival after operation.

In the series reported by Earnest, Kernohan and Craig there were 112 patients who left the hospital and from 107 of these some follow-up record was obtained. The average survival period of this group from the time of operation until death or until the patient was last heard from was 48 months, but this figure alone is not of great significance, as the authors pointed out. Many of the living patients had not yet had the opportunity of long survival and thus add to the general average. These authors further clearly showed that a far greater percentage of patients was living after what were termed complete removals than those who had had partial removals or biopsies, so that the eventual survival in the more complete operations would undoubtedly be greater as time went on.

In the series from Olivecrona's clinic the average survival period after operation was 5 years and 3 months, with the longest survival $17\frac{1}{2}$ years. In this article[15] there is a complete tabulation of all the cases as to the type of operation and the survival period of each patient. From a study of this table it is apparent that the radical operations accomplished much more than

the nonradical ones, the average survival in the former being just under 7 years, whereas in the latter it was about $3\frac{1}{3}$ years.

In Cushing's series of 2,000 verified brain tumors reported in 1932 there were 27 oligodendrogliomas. Although no statistics of survival were given in this monograph, a further record of these patients was reported by Eisenhardt in 1935. At that time 1 of the patients was still living 9 years following operation, and 5 others had lived from 5 to 13 years.* The vast majority of all these patients were subjected to as complete tumor removals as possible.

## PRESENT STUDY

In the present series of 26 patients, there were 17 males as compared to 9 females, with a ratio of a little less than 2 to 1. The age incidence showed an average of 38.9 years with the youngest 15 and the oldest 53 years. The longest probable preoperative duration of symptoms was 12 years in a patient who had recurrent convulsive seizures but since he had also had a cranial injury the etiology of his seizures may be questionable. The average period of preoperative symptoms was 28.6 months, with the shortest 2 months.

Among the preoperative symptoms were seizures in 13 patients (50 per cent) and headaches in 17 (65.4 per cent). Definite papilledema was observed in 14 patients (53.8 per cent). The rest of the symptoms in varying degrees were weakness of extremities, visual disturbance, aphasia, mental retardation, confusion, memory defect, personality change and other pressure symptoms, especially toward the later stages of the disease. Of the 19 patients with intrahemispheric tumors reported by Shenkin *et al.*,[17] 12 (63.1 per cent) had epileptic seizures prior to operation. Since none of their 6 patients in the intraventricular group had preoperative seizures it would mean that 48 per cent of their whole group had such attacks, a percentage similar to ours. Our 2 patients with intraventricular tumors were also free from seizures prior to operation. Bailey and Cushing[2] called attention to the fact that when people of middle life begin to have epileptiform attacks of obscure etiology, the possible existence of one of these slow-growing lesions must always be borne in mind.

Only 9 of our patients (34.6 per cent) showed calcification in the x-ray films, although a few of the older records had no information with reference to skull films before an air injection had been made.

Twenty (76.9 per cent) of the tumors were hemispheric, 2 (7.7 per cent) intraventricular and 4 (15.4 per cent) cerebellar. Of the cerebral group, 7 (26.9 per cent) were located in the frontal lobe. Five others were in the frontotemporal region. The 4 cerebellar tumors were equally divided as to laterality.

Nine (34.6 per cent) of the 26 patients had more than one operative procedure, with 1 patient surgically treated five times. This patient had

* Two other patients subsequently classified as having oligodendrogliomas were still living and were later operated upon by one of us (G.H.). These patients are, therefore, included in our present series.

been operated on twice previously by Dr. Cushing and survived 45 months. One patient died from a gastric hemorrhage following a second operation after surviving in fairly normal condition for 48 months. Three patients were previously operated upon elsewhere, 2 by Dr. Harvey Cushing and 1 by Dr. Jason Mixter.

*Postoperative Survival.* Four of our 26 patients died postoperatively, giving a case mortality rate of 15.3 per cent. This figure is for all patients dying in the hospital from whatever cause. Our mortality, therefore, is the same as Cushing's case mortality of 15.4 per cent for oligodendrogliomas as well as that of Olivecrona, 15.3 per cent, but somewhat less than in other reported series which has ranged from 20 to about 25 per cent. Elvidge, Penfield and Cone, however, had no postoperative deaths in their 9 cases in 1935 and Cushing had no deaths among the last 13 patients he operated upon.

Excluding the 4 patients who died in the hospital following operation, there were 22 patients who lived from a few months to many years after their discharge. In some instances our follow-up data are incomplete, but of the 17 from whom we have heard after any length of time, however short, the average duration of life has been 87 months, or just over 7 years. Seven patients have lived from 5 to 10 years, 2 patients have lived 18 years (with 1 still living and well), and 1 patient survived 33 years. In this instance the original operation was performed by Dr. Cushing in 1916 with subsequent operations by the senior author in 1943 and 1946. The patient finally died in 1949.

Six (23.1 per cent) of our 26 patients are still living at the time of this report. Their postoperative survival periods are respectively 216 months, 168 months, 84 months, 76 months, 58 months and 19 months. Two of these patients are retarded mentally to a slight degree. Three have returned to work, although one of these has occasional dreamy states. Our latest patient who had a cerebellar tumor is alive 19 months after operation. He still walks on a wide base and has some residual ataxia of his left extremities. He has also had several seizures, as he did preoperatively.

Six (23.1 per cent) of the tumors revealed foci of astrocytes while the predominant histologic characteristics were those of oligodendroglioma. One other patient, whose verified oligodendroglioma was subtotally removed at the original operation, showed at a subsequent operation almost 2 years later a recurrent tumor with marked histologic changes toward glioblastoma. This patient is still living, but has residual weakness of his right extremities and marked aphasia.

Eight (30.8 per cent) of the cerebral tumors showed cystic areas. In only 2 cases were there definite mitoses with areas showing rapid growth.

## DISCUSSION

According to Bucy,[6] oligodendrogliomas form 4 per cent of all gliomas. Our series of 26 similar tumors from a total of 680 gliomas gives a close percentage of 3.8. In Cushing's group of 862 gliomas there were 27 oligodendro

gliomas or 3.1 per cent, but Olivecrona's percentage (6.7 per cent) is distinctly higher. From a review of the literature several series reports are shown in Table 1, indicating the fairly rare occurrence of this tumor.

In the large series of 165 verified oligodendrogliomas reported from the Mayo Clinic by Earnest, Kernohan and Craig, the authors pointed out, as have most others, that tumors of this type are chiefly cerebral in origin, 151 of their patients having growths above the tentorium and 14 below this structure. They classified the tumors as oligodendrogliomas and oligodendroblastomas according to differences in their microscopic appearance but

TABLE 1

*Frequency of occurrence of oligodendrogliomas**

| Series | Total Gliomas | Oligodendrogliomas | Percentage of Oligodendrogliomas |
|---|---|---|---|
| Cushing (1932) | 862 | 27 | 3.1 |
| Greenfield and Robertson (1933) | 230 | 9 | 3.9 |
| Elvidge, Penfield and Cone (1935) | 467 | 8 | 1.7 |
| Löwenberg and Waggoner (1939) | 420 | 21 | 5.0 |
| Reymond and Ringertz [Olivecrona] (1950) | 773 | 52 | 6.7 |
| Lahey Clinic (1951) | 680 | 26 | 3.8 |

* In the series reported by Shenkin, Grant and Drew,[17] and the one by Earnest, Kernohan and Craig,[8] the total number of gliomas was not mentioned, so the percentage of oligodendrogliomas is not available.

could not relate this classification to survival periods, nor could any satisfactory system of grading be devised. They estimated the life span of the tumor, from the onset of symptoms until the death of those patients who survived operation and left the hospital, as being somewhere between 8 and 14 years, "and may be much longer."

In the present series, 20 were cerebral, 2 intraventricular, and 4 cerebellar. This is a higher percentage of cerebellar oligodendrogliomas than has been reported in any similar series. In Bailey and Cushing's[2] series of 9 cases, 7 were cerebral and 2 were in the septum pellucidum. Elvidge, Penfield and Cone[10] reported 8 cases, all of which were cerebral. In the series of Shenkin *et al.*,[17] except for the 6 intraventricular tumors, 19 were of the cerebral variety. Greenfield and Robertson[11] found 1 oligodendroglioma in the fourth ventricle in a series of 5 cystic oligodendrogliomas. None of the 4 cerebellar tumors in our series was cystic. The patients with cerebellar tumors tended to have a much shorter period of preoperative symptoms, the duration in 3 patients being 2, 3, and 3 months, while in the fourth this period was 36 months. Two of these patients are still alive; the one with the longest period of preoperative symptoms is living a normal and useful life 76 months after operation. The other patient was operated on too recently to evaluate.

Earnest, Kernohan and Craig,[8] Löwenberg and Waggoner,[13] Shenkin *et al.*,[17] as well as Reymond and Ringertz,[15] have shown that cerebral oligo-

dendrogliomas have a predisposition to occur in the frontal lobes. These observers also found several tumors with involvement of both frontal lobes. In our series unilateral frontal lobe involvement was present in 7 cases. Five other tumors, however, showed invasion of both frontal and temporal lobes.

Of the intraventricular tumors Shenkin *et al.*[17] pointed out that the average preoperative duration of symptoms was $7\frac{2}{3}$ months with a range of 3 to 11 months. The preoperative period of symptoms in our 2 patients with intraventricular tumor was $4\frac{1}{2}$ and 12 months respectively, an average of $8\frac{1}{4}$ months. One of these patients survived only 2 months while the other lived a useful life for 12 years following subtotal extirpation of the neoplasm. It may be pointed out that this patient had only a subtemporal decompression 33 months prior to the second operation when the tumor was attacked directly. The survival period for this patient is, therefore, calculated from the time of the subtotal removal of the tumor.

*Postoperative Survival.* Our conviction agrees entirely with that expressed by Earnest, Kernohan and Craig that the longest and most satisfactory postoperative periods are obtained by radical tumor extirpation. In the vast majority of our patients an attempt was made to remove all visible tumor tissue, but obviously with this type of growth an absolutely complete excision can never be assured.

We believe that the policy of performing radical, or what may be called grossly total excisions of all gliomas should be emphasized vigorously. There are obvious, but certainly infrequent, exceptions to this policy, for example when to attempt such an operation would leave a patient so crippled that life would be useless. However, even when tumors appear to involve important areas, their removal will often restore function rather than destroy it. Furthermore, it cannot be told with certainty by the gross appearance of a glioma nor by an immediate biopsy the exact nature of the growth or how relatively benign or malignant it may be. At times even glioblastomas will give unexpectedly good results, and certainly with many astrocytomas and the majority of oligodendrogliomas an excellent useful survival may be accomplished. The average of over 7 years in the present series would seem to be conclusive evidence in this respect.

Elvidge, Penfield and Cone[10] noted that the postoperative survival periods of their 8 cases of oligodendroglioma were disproportionately lower than the preoperative duration of symptoms. Although this was true among some of our patients, the majority showed the reverse order. Perhaps the attempt at a radical total extirpation in every case at the time of the first operation has altered this observation statistically.

## SUMMARY

Twenty-six cases of histologically verified oligodendrogliomas have been presented with special reference to duration of preoperative symptoms, location of the neoplasms and survival period postoperatively. A comparison

is made with some similar series reports with the purpose of further evaluating the nature of oligodendrogliomas occurring intracranially.

Although some of the tumors showed mitotic figures histologically, they were relatively few. Only one showed abundant mitoses. These occurred in a recurrent tumor 2 years after the original operation. It may be concluded that although oligodendrogliomas occasionally grow wild, as they have been observed to do by other investigators, they are in the main slow growing so that every effort should be made to remove them as completely as possible when encountered.

Longer survival periods after radical tumor extirpation are evident from the study of previously reported cases, and this policy is likewise substantiated in the present series by an average postoperative survival period of over 7 years.

## REFERENCES


1. Bailey, P., and Bucy, P. C. Oligodendrogliomas of the brain. *J. Path. Bact.*, 1929, *32:* 735–751.
2. Bailey, P., and Cushing, H. A classification of the tumors of the glioma group on a histogenetic basis with a correlated study of prognosis. *Philadelphia: J. B. Lippincott Co.*, 1926, 175 pp. (see pp. 144–146).
3. Bailey, P., and Hiller, G. The interstitial tissues of the central nervous system: a review. *J. nerv. ment. Dis.*, 1924, *59:* 337–361.
4. Beck, D. J. K., and Russell, D. S. Oligodendrogliomatosis of the cerebrospinal pathway. *Brain*, 1942, *65:* 352–372.
5. Blumenfeld, C. M., and Gardner, W. J. Disseminated oligodendroglioma. *Arch. Neurol. Psychiat., Chicago*, 1945, *54:* 274–279.
6. Bucy, P. C. Intracranial tumors. In: Grinker, R. R. *Neurology.* Springfield, Ill.: Charles C Thomas, 1943, 3rd ed., 1136 pp. (see p. 570).
7. Cushing, H. Intracranial tumours. Notes upon a series of two thousand verified cases with surgical-mortality percentages pertaining thereto. *Springfield, Ill.: Charles C Thomas*, 1932, xii, 150 pp. (see pp. 49–56).
8. Earnest, F., III, Kernohan, J. W., and Craig, W. M. Oligodendrogliomas. A review of two hundred cases. *Arch. Neurol. Psychiat., Chicago*, 1950, *63:* 964–976.
9. Eisenhardt, L. Long postoperative survivals in cases of intracranial tumor. *Res. Publ. Ass. nerv. ment. Dis.*, 1937, *16:* 390–416.
10. Elvidge, A., Penfield, W., and Cone, W. The gliomas of the central nervous system. A study of two hundred and ten verified cases. *Res. Publ. Ass. nerv. ment. Dis.*, 1937, *16:* 107–181.
11. Greenfield, J. G., and Robertson, E. G. Cystic oligodendrogliomas of the cerebral hemispheres and ventricular oligodendrogliomas. *Brain*, 1933, *56:* 247–264.
12. Kernohan, J. W. Tumors of the central nervous system. *Proc. Mayo Clin.*, 1938, *13:* 827–832.
13. Löwenberg, K., and Waggoner, R. W. Gross pathology of the oligodendrogliomas. *Arch. Neurol. Psychiat., Chicago*, 1939, *42:* 842–861.
14. Martin, J. P. Two cases of oligodendroglioma: with remarks on the general clinical features of such cases. *Brain*, 1931, *54:* 330–349.
15. Reymond, A., and Ringertz, N. L'oligodendrogliome. Étude anatomo-clinique de 74 cas. *Schweiz. Arch. Neurol. Psychiat.*, 1950, *65:* 221–254.
16. Russell, J. R., and Bucy, P. C. Oligodendroglioma of the spinal cord. *J. Neurosurg.*, 1949, *6:* 433–437.
17. Shenkin, H. A., Grant, F. C., and Drew, J. H. Postoperative period of survival of patients with oligodendroglioma of the brain. Report of twenty-five cases. *Arch. Neurol. Psychiat., Chicago*, 1947, *58:* 710–715.

# MORGAGNI'S SYNDROME AND BRAIN TUMORS

## A NOTE*

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IN THE course of a study of idiopathic, symmetrical hyperostosis of the skull which is a feature of the condition known as l'hyperostose frontale interne, Stewart-Morel syndrome, hyperostosis frontalis interna, metabolic craniopathy and Morgagni's syndrome, especial attention was attracted to associated and complicating diseases.

The material is based on the Roentgen examination of the skull of 10,064 individuals, 5,188 females and 4,876 males of all ages, made in a period of 10 years. Among them were 627 females and 55 males having hyperostosis.

The records of the hospitalized patients were analyzed for the purpose stated above with particular attention to the coexistence of hyperostosis and intracranial tumor. One reason for this was the fact that many patients eventually found having hyperostosis are referred for x-ray examination with the provisional diagnosis of "suspected brain tumor." An additional reason was that if there were any association of hyperostosis and neoplasm, its nature and type might be ascertained.

For a control 1,073 consecutive case histories of patients free of all evidence of hyperostosis were studied in an identical fashion: 450 females and 623 males.

For greater accuracy only cases in the second and seventh decades inclusive were tabulated. Above the seventh there were too few cases in both hyperostotics and controls and before the second decade there were no examples of hyperostosis and a fairly large number of tumors among the controls. This method of exclusion reduces somewhat the total figures given above, but furnishes a truer aspect of association, if there is any.

All tumors were verified either surgically or by autopsy. Those patients entering the hospital with recurrence after operation elsewhere were omitted from this analysis as were those with intracranial aneurysm, 2 in number, extensions from extracranial tumors, and bone tumors of the skull itself. The occurrence of hyperostosis and intracranial tumor is shown in Table 1.

The incidence of tumor in the female hyperostotics is 6.22 per cent and in the controls 6.14 per cent. For the males the values are 2.27 per cent and 7.86 per cent respectively.

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Except for the meningeal fibroblastoma there is no significant relationship between hyperostosis and intracranial neoplasm. In view of the fact that there are observers who believe that there is some unknown factor that so affects the dura that hyperostosis ensues, it is conceivable that the same agency plays a part in the development of meningeal fibroblastoma. The disparity in the incidence of this tumor in the sexes is impressive. Tumor in hyperostosis is of fortuitous occurrence and vice versa. However, symptoms in the two conditions are often indistinguishable. Therein lies the greater danger on the one hand of overlooking an intracranial neoplasm and on the other, the lesser hazard, of operating on a patient in the absence of a tumor. The writer knows of 2 cases of the latter, 1 in the material of this study. There were no ill effects from the operation and the patients had the happy assurance that they did not have a brain tumor. Differentiation between the two conditions is most difficult and is indeed, for a period at least, almost impossible.

This is written in the hope that it might in some measure aid in clarifying the problem of diagnosis in the two conditions.

TABLE 1

*Intracranial neoplasm and hyperostosis*

| Neoplasm | Female | | Male | |
|---|---|---|---|---|
| | Hyperos. | Control | Hyperos. | Control |
| Spongioblastoma multiforme | 5 | 9 | 0 | 13 |
| Meningeal fibroblastoma | 10 | 6 | 0 | 2 |
| Astrocytoma | 4 | 6 | 0 | 11 |
| Acoustic neuroma | 3 | 2 | 0 | 2 |
| Chromophobe adenoma, pituitary | 2 | 3 | 1 | 0 |
| Ependymoma | 0 | 0 | 0 | 5 |
| Metastatic carcinoma | 3 | 1 | 0 | 3 |
| Suprasellar cyst | 0 | 0 | 0 | 4 |
| Cholesteatoma | 1 | 1 | 0 | 2 |
| Oligodendroglioma | 0 | 0 | 0 | 3 |
| Medulloblastoma | 0 | 0 | 0 | 2 |
| Pinealoma | 0 | 0 | 0 | 1 |
| Hemangioblastoma | 0 | 0 | 0 | 1 |
| Total | 28 | 28 | 1 | 49 |

# COMPRESSION OF SPINAL CORD BY OSTEITIS DEFORMANS (PAGET'S DISEASE), GIANT-CELL TUMOR AND POLYOSTOTIC FIBROUS DYSPLASIA (ALBRIGHT'S SYNDROME) OF VERTEBRAE

## A REPORT OF FOUR CASES

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SPINAL cord compression by a lesion of the vertebra is most often the result of traumatic injury, metastatic carcinoma, infiltrating sarcoma, tuberculous spondylitis, pyogenic osteomyelitis, osteoarthritis, infiltrating leukemia or multiple myeloma. Primary osteogenic sarcoma and benign neoplasms of the spine rarely cause compression of the spinal cord. Although osteitis deformans (Paget's disease) is not an uncommon disease and frequently involves the spine, it rarely causes compression of the spinal cord. Polyostotic fibrous dysplasia belongs to the rare category of bone disease. The vertebrae are scarcely ever affected, and involvement of the spinal cord has never before been recorded in this condition to our knowledge.

### OSTEITIS DEFORMANS

Among 274,397 admissions to the Mount Sinai Hospital in a period of 17 years from October 1933 to October 1950, 131 were for osteitis deformans, an incidence of approximately 1 to every 2,000 admissions. Of these patients, only 1 had paraplegia as a result of spinal cord compression by the hypertrophic vertebrae. Following is a brief report of this case:

Case 1. *G.F., male, aged 65. Osteitis deformans involving upper dorsal vertebrae. Paraplegia. Laminectomy of D1, D2 and D3. Improved.*

Fifteen months before admission the patient began to have difficulty in walking, associated with numbness of both lower extremities. For the last 3 weeks he had been unable to walk unless assisted and could not stand without support.

*Examination.* There was marked weakness in both lower limbs, especially the left. The ankle jerk was absent on the left and markedly exaggerated on the right. Other deep tendon reflexes of the lower limbs were all exaggerated but equal on both sides. Signs of Babinski, Chaddock, Oppenheim and Rossolimo were elicited on both sides. Hypalgesia was demonstrated from below D4. Vibration sense was absent from below the D4 spinous process. Deep and position sensation were lost from below the ankles. Abdominal reflexes were all present and equal on both sides. There was a kyphosis of the upper dorsal spine.

Laboratory findings: Hb. 15 gm., WBC 6,550 with 61 per cent neutrocytes. E.S.R. 15 mm./hr., fasting sugar 140 mg. per cent, urea nitrogen 17 mg. per cent,

FIG. 1. *Case 1.* Paget's disease. Posteroanterior view of dorsal spine showing coarsened trabecular pattern of the upper segments.

serum albumin 3.4, globulin 3.0, acid phosphatase 8 KAU, alkaline phosphatase 40 KAU, cholesterol 480 mg. per cent, phosphorus 3.1 mg. per cent, and calcium 10.5 mg. per cent.

Roentgenograms of spine and pelvis revealed loss of normal homogeneous cortical density of the bones of the pelvis and almost all of the vertebral bodies. The cortex was thickened and the trabeculae were markedly coarsened by a wavy thick bony meshwork with radiolucent interstices. Small cyst-like areas were scattered between the heavy trabeculae. There was marked flattening of the D3 vertebra with a similar coarsened trabecular pattern and biconcavity of its upper and lower surfaces (Fig. 1). The skull showed several small areas of decreased density as well as a generalized sclerosis. Diagnosis: Generalized osteitis deformans (Paget's disease).

FIG. 2. *Case 1.* Paget's disease. Myelogram showing obstruction at level of D3.

*Course.* On the 11th hospital day, myelography was done. Before the instillation of pantopaque, manometric test disclosed a complete block of the CSF flow. The fluid was xanthochromic. The myelogram revealed a complete block to the cephalad flow of the pantopaque at the level of the D3 vertebra (Fig. 2). There was an irregular rounded capping to the proximal end of the column, suggesting an extradural lesion.

*Operation.* On the next day laminectomy was

performed with the removal of D1, D2 and D3 laminal arches, which were soft, vascular, and about 1½ cm. in thickness. The spinal cord did not pulsate until the thickened laminal arch of D1 had been completely removed. Epidural probing with a small-calibre rubber catheter encountered no obstruction in the neighboring segments of the spinal canal. Intradural exploration disclosed a thickened arachnoid membrane and fine fibrous adhesions.

*Postoperative Course.* The right leg was completely paralyzed. The power of the left lower leg was further reduced. There was complete anesthesia from below the level of D3. However, the strength of the left lower limb slowly improved. On the 37th postoperative day, he could raise his left leg and sensation on the right side of the body and leg recovered completely.

One week later, the power of the left leg was about normal. He could raise his right leg off the bed. However, sensation remained absent on the left from below D4. Lumbar puncture revealed a CSF pressure of 80. The fluid was clear and contained 72 mg. per cent total protein. Manometric test showed that there was no obstruction.

On discharge, 85 days after operation, the patient was walking with crutches.

*Pathological Diagnosis.* Osteitis deformans (Fig. 3).

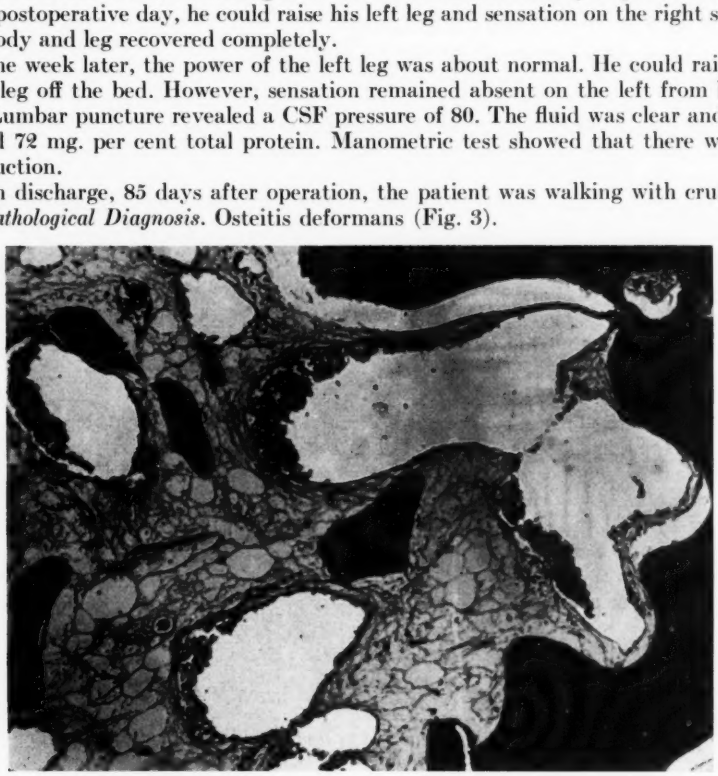

FIG. 3. *Case 1.* Paget's disease. Section of bone removed from lamina. There are dense trabeculae among vacuolated tissue and dilated vascular sinuses. Hematoxylin-eosin stain, ×100.

*Comment.* The paraplegia in Case 1 was caused by the hypertrophic laminal arches of D1, D2 and D3. The laminectomy benefited the patient. However, recovery of function has been slow, but progressive.

Osteitis deformans is a chronic disease and does not in itself endanger life. The patients may live for many years, dying either from its complications or other causes. They may be unaware of having the disease for many years and usually do not enter a hospital unless a complication develops.

Paget's original observation that the most frequent sites of osteitis deformans are in the skull or tibia has been disproved. Careful anatomic study by Schmorl[26] in 190 autopsies proved that osteitis deformans occurs most frequently in the sacrum, spine and femur.

Since Sir James Paget[20] first described the disease in 1876, numerous cases of involvement of the central nervous system, such as platybasia, convexobasia, optic atrophy, deafness and trigeminal neuralgia as a result of destruction and distortion of the base of the skull, have been recorded.[7] Nevertheless, cord compression is rare and it was not until 1923 that the first real evidence of the production of spinal cord symptoms by Paget's disease was brought forward by Wyllie,[32] who reported 2 cases. In 1939, Schwarz and Reback[27] reported 9 cases of paraplegia due to osteitis deformans of the spine. In 1940, Turner[28] added another series of 7 cases to the medical literature. From 1923 up to the present, a total of 37 cases have been recorded (Table 1).

Only 3 of these 37 patients were females. The oldest was 77 and the youngest was 43 years of age. The longest duration of Paget's disease before the onset of neurological symptoms was 20 years. In our case the compression of the spinal cord was the first symptom of the illness.

Osteitis deformans involves the lumbar spine more frequently than the dorsal. In 69 autopsied cases in which the spine was involved, Schmorl[26] found 36 in the lumbar, 23 in the dorsal and 10 in the cervical spine. Spinal cord compression occurred most frequently when the thoracic region was involved. As shown in Table 1, in 31 of these 37 collected cases, the compression of the cord was at the level of the dorsal vertebrae. In only 3 instances was the lesion localized in the cervical segments, and in the remaining 3 the level was not mentioned. However, 2 of these patients had paraplegia and 1 had paraparesis; presumably the dorsal spine was the site of compression.

As far as treatment is concerned, there is no choice other than the removal of the pressure by a laminectomy. In 20 of the 37 reported cases laminectomy was performed. Fourteen patients improved, 3 died from postoperative complications, 2 did not improve, and 1 was able to walk for 3 years and then again became paraplegic. Of the patients who were not operated upon, none improved.

## GIANT-CELL TUMOR

In 17 years, 2 cases of giant-cell tumor of the spine with compression of the cord were encountered at the Mount Sinai Hospital. One has been reported previously,[14] and is therefore not included in the present series. The patient was a 22-year-old woman. Spastic paraplegia developed 8 days before admission. Laminectomy of D2 to D4, with the removal of the tumor which involved the lamina of D2, restored her motor power. She made a complete recovery.

The other case is reported below (Case 2). In this instance the tumor of the vertebra involved the cauda equina.

TABLE 1

*Cases of Paget's disease with spinal cord compression reported from 1923 to 1951.*

| No.—Author | Date | Sex | Age | X-ray Findings & Neurological Signs | Treatment & Result |
|---|---|---|---|---|---|
| 1. Wyllie[32] | 1923 | M | 55 | Thoracic vert. Parapar. Sensory level 3rd costal cart. | Laminect. D2–4. Improved |
| 2. Wyllie[32] | 1923 | M | 63 | D4–5. Spastic parapleg. Anesth. below xiphoid proc. | Laminect. Died |
| 3. Ardin-Delteil *et al.*[3] | 1923 | M | 55 | Spastic parapleg. in flex. Hypal. below pubis. | No specific treatment |
| 4. Kay *et al.*[15] | 1934 | M | 52 | Spastic parapleg. in flex. Anesth. below L4. Hypal. D10. | No specific treatment |
| 5. Kay *et al.*[15] | 1934 | M | 54 | Spastic parapar. Hypal. below D3. | No specific treatment |
| 6. Vincent *et al.*[30] | 1936 | M | 57 | D6–10. Parapleg. Sensory changes lower limbs. CSF, complete block. | Laminect. D5–7. Recovery |
| 7. Petit-Dutaillis *et al.*[22] | 1936 | M | 57 | Thoracic vert. Spastic parapleg. Sensory level D6. CSF, complete block; xantho. | Laminect. D3–8. Recovery |
| 8. Gutman & Kasabach[11] | 1936 | M | 54 | Parapleg. No detail. | Not mentioned |
| 9. Garcin *et al.*[9] | 1937 | M | 61 | Brown-Séquard, level C3–4 | No treatment |
| 10. Haguenau *et al.*[12] | 1937 | M | 47 | D4–9. Parapar. Sensory level D7. | Laminect. D5–9 |
| 11. Alessi[2] | 1938 | M | 64 | D4–7. Parapleg. CSF, complete block; xantho. | Laminect. D4–8. Died |
| 12. Petersma[21] | 1938 | M | 51 | D11–12, L1. Transverse lesion cord. CSF, complete block. | No op. |
| 13. Schwarz & Reback[27] | 1939 | F | 55 | D9. Flaccid parapar. Sensory level D9. | Laminect. D8–10. Recovery |
| 14. Schwarz & Reback[27] | 1939 | F | 46 | D6–9. Spastic parapar. Sensory level D9–10. CSF, complete block. | Laminect. D5–9. Recovery |
| 15. Schwarz & Reback[27] | 1939 | M | 52 | D4–9. Spastic parapar. Sensory level D8. CSF, complete block. | Laminect. D4–8. Died |
| 16. Schwarz & Reback[27] | 1939 | M | 58 | Mid-thoracic vert. Parapar. Sensory level: lt. D4; rt. D1. CSF, partial block. | No op. |
| 17. Schwarz & Reback[27] | 1939 | M | 72 | Spastic parapar. Sensory level D10. | No op. |
| 18. Schwarz & Reback[27] | 1939 | M | 57 | D4–7. Parapar. Sensory level D4. | No op. |
| 19. Schwarz & Reback[27] | 1939 | M | 43 | D3–12. Parapar. Sensory level D3. CSF, complete block. | No op. |
| 20. Schwarz & Reback[27] | 1939 | M | 70 | All thoracic & lumbar spine. Spastic parapleg. Sensory level D5. | No op. |
| 21. Schwarz & Reback[27] | 1939 | M | 60 | D6. Spastic parapar. Sensory level D6. CSF, complete block. | No op. |
| 22. Elkington[8] | 1939 | M | 70 | No detail. Spastic parapar. | No op. |
| 23. Turner[28] | 1940 | M | 52 | D2–7. Parapar. Hypal. below D7. CSF, complete block; protein 4,800 mg.%; xantho. | Laminect. D2–4. Recovery |
| 24. Turner[28] | 1940 | M | 60 | C4–D5. Parapar. Sensory level D4. CSF, complete block; protein 600 mg.%; xantho. | Laminect. D2–8. Improved |

TABLE 1—*Cont.*

| No.—Author | Date | Sex | Age | X-ray Findings & Neurological Signs | Treatment & Result |
|---|---|---|---|---|---|
| 25. Turner[28] | 1940 | M | 60 | D2–5. Painful spastic parapleg. in flex. Sensory level below D5. | Laminect. D2–5. Not improved |
| 26. Turner[28] | 1940 | M | 66 | C7–D8. Parapar. Hyal. below D6. Retention urine. | Laminect. D2–6. Improved |
| 27. Turner[28] | 1940 | M | 58 | D3–5. Painful spastic parapar. Sensory level D9. | Laminect. D2–6. Slow recovery. Parapleg. 3 years later |
| 28. Turner[28] | 1940 | M | 46 | Parapar. Retention urine. Sensory level D6. CSF, complete block; xantho; protein 2,000 mg. %. | Laminect. D1–5. Died |
| 29. Turner[28] | 1940 | M | 77 | C6–D2. Spastic parapar. Anesth. below D6. | No op. |
| 30. Hillman[13] | 1941 | M | 63 | D4–6. Parapar. Sensory level D6–10. CSF, complete block; xantho. | Laminect. D4–6. Improved |
| 31. Hillman[13] | 1941 | F | 44 | C6. Sensory level C4. | Laminect. C5–7. Not improved |
| 32. Gross[10] | 1942 | M | 53 | D5–6. Spastic parapleg. in exten. CSF, complete block; xantho. | Laminect. D5–6. Recovered |
| 33. Whalley[31] | 1946 | M | 66 | Atlas, axis & L3. Quadripleg. Sensory level below clavicles. | No op. Died |
| 34. Rabiner & Hand[23] | 1947 | M | 56 | No detail. Sensory change D6. Parapar. | Not mentioned |
| 35. Rabiner & Hand[23] | 1947 | M | 58 | Lumbar spine; spastic parapar. | Not mentioned |
| 36. Colclough[5] | 1949 | M | 50 | Spastic parapleg. Sensory level D9–10. | Laminect. D5–9. Recovered |
| 37. Teng, Gross & Newman | 1951 | M | 65 | Whole spine. Parapar. Hypal. below D4. CSF, complete block. | Laminect. D1–3. Improved |

Case 2. *N.J., male, aged 22. Giant-cell tumor of L3 laminal arch causing weakness in legs, especially the left. Laminectomy of L2 and L3. Complete recovery.*

While the patient was at work pushing a hamper, 2½ years before admission, a sharp pain suddenly developed in the middle and lower part of the back. Two weeks later the pain became worse, and he was unable to work. A few months later the pain was much less than before; however, he was still incapacitated. Five weeks before admission, the pain became more severe. One week later his left leg felt heavy and weak, and he could not stand on it. Two weeks before admission the weakness involved the opposite leg.

*Examination.* There was a marked limitation of motion of the spine in any direction. The muscles of the back were spastic. Tenderness was elicited over the spinous process of L3. His gait was slow, awkward and unsteady. There was weakness in both legs, especially the left. Both ankle jerks were absent. Hypalgesia was found below L1 on both sides. There was muscular atrophy of the lower lumbar group, the calves and the thighs.

Laboratory findings were noncontributory. X-ray of the lumbar spine disclosed an expanding lesion involving the left side of L3 laminal arch. There was evidence of bone destruction associated with irregular patterned new bone formation.

*Course.* On the day after admission a lumbar puncture was done. The CSF was clear, containing 3 lymphocytes. Pandy test was 2+. Manometric study showed that there was no block.

*Operation.* On the 5th hospital day, laminectomy of L2 and L3 was performed by Dr. Ira Cohen. The tumor was found to involve the laminal arch, the left pedicle and part of the vertebral body of L2. It was reddish in color and very vascular. It extended into the epidural space and encroached upon the cauda equina. Some newly formed bone tissue was seen inside the tumor.

*Course.* Two weeks after operation, radiotherapy was initiated. Four weeks later the patient was discharged. All neurological signs were normal. He was last seen on April 5, 1949 and remained asymptomatic.

*Pathological Diagnosis.* Giant-cell tumor of the spine.

In the second case of giant-cell tumor included in this report (Case 3), the patient was treated by one of us at the Beth Israel Hospital.

Case 3. *F.Z., female, aged 15. Giant-cell tumor of C6 causing quadriparesis. Laminectomy of C5, C6 and C7. Improved.*

One year before admission, the patient noted weakness in both arms and legs associated with pain in the back of the neck radiating down to the arms. Six weeks before admission the pain became worse and 4 weeks later she was unable to stand. A feeling of girdle-like constriction had developed around the upper chest.

*Examination.* There was tenderness over the spinous process of C6 and C7. The neck was held stiff with limitation of motion. There was weakness of all four limbs with atrophy of the intrinsic muscles of both hands. Deep tendon reflexes of all extremities were markedly exaggerated. Abdominal reflexes were absent. A zone of hyperesthesia was elicited at the level of C6. Below this zone there was hypalgesia. Vibration sense was impaired in both legs.

Laboratory findings: CSF pressure was 180 mm., with partial block on manometric test. The fluid contained 5 WBC and 128.6 mg. per cent total protein.

X-ray of cervical spine disclosed a compressed fracture-dislocation of C6. Biopsy of the spine was reported as benign giant-cell tumor (Fig. 4).

*Operation.* On the 8th hospital day, laminectomy of C5, C6 and C7 was done.

*Course.* Six days after operation a cast was applied and x-ray treatment was initiated. She made a slow but satisfactory improvement in regaining the function of her limbs. On discharge she was walking about, using a walking aid.

*Comment.* Giant-cell tumor is relatively uncommon, probably half as frequent as primary malignant bone tumor. Its occurrence in the spine is comparatively rare. Kolodny,[16] in an analysis of the material of the Bone Registry in 1927, found that giant-cell tumor occurred in the spine in 8 per cent of the cases. It affects mainly the younger group of patients, in the second and the third decades of life.

Of 124 patients with giant-cell tumor seen at the Mayo Clinic[19] from 1916 to 1940, in only 2 was the tumor located in the vertebra and none had signs of spinal cord compression. Coley[6] listed 509 cases of giant-cell tumor in his book *Neoplasms of Bone;* only 3 were found in the spine.

It is now generally agreed that while the majority of giant-cell tumors are benign, some are either malignant from the onset or undergo malignant

changes. Of the 124 cases reported from the Mayo Clinic,[19] in 101 the lesions were benign.

Since this tumor is susceptible to x-ray treatment, it is usually treated before symptoms of spinal cord compression arise. Only a few cases of giant-cell tumor involving the spinal cord or cauda equina have been reported. Lewis,[17] in reviewing the literature to 1924, found 17 cases of primary giant-cell tumor of the vertebra. In 11 of these patients there were signs of pressure on the spinal cord or cauda equina. In 1930, Santos[24] collected 23 cases of

FIG. 4. *Case 3.* Giant-cell tumor of spine. Section of bone removed from lamina. Giant cells are shown in orderly spindle- and oval-cell matrix. Hematoxylin-eosin stain, ×100.

giant-cell tumor of the spine, and reported 1 of his own with cauda equina compression. Brock and Bogart[4] in 1945 collected 91 cases, and added 1 with spinal cord compression at the cervical segment. In 1947 Verbiest[29] recorded another case of cord compression. Therefore, we have been able to collect 17 cases from the literature including the 1 reported by Kaplan[14] in 1942 and our own 2 cases.

Laminectomy for decompression, followed by radiotherapy, gave satisfactory results in 6 cases recently reported.[4,14,24,29]

## POLYOSTOTIC FIBROUS DYSPLASIA (ALBRIGHT'S DISEASE)

A perusal of the literature failed to disclose a case of spinal cord compression due to ostotic fibrous dysplasia. The following is a case of polyostotic fibrous dysplasia involving the mid-thoracic vertebrae, associated with paraplegia.

Case 4. *B.L., female, aged 37. Polyostotic fibrous dysplasia involving D7 and D8*

*with spinal cord compression. Laminectomy of D5, 6, 7. Complete recovery. Recurrence of paraplegia 15 months later. Re-exploration from D4 to D7. Slow recovery.*

In 1929 the patient noted a small tender tumor on the right side of the posterior chest wall, and a similar one on the left side, anteriorly situated. Later a section of one rib was removed and a diagnosis of fibrous dysplasia was made.

In December 1942, while walking, she suddenly had weakness and numbness in both legs, accompanied by severe pain in the posterior mid-thoracic region. The numbness was more marked in the right foot, and the weakness was progressing to the time of admission 2 weeks later.

*Examination.* There was a large bulging tender mass over the 7th and 8th ribs on the right side. Tenderness was found over the spinous processes from D4 to D9

FIG. 5. *Case 4.* Polyostotic fibrous dysplasia. Posteroanterior view of the dorsal spine, showing destruction of right 7th and 8th and left 7th rib, and of the 6th, 7th and 8th vertebrae.

and a kyphos at D6 and D7. The gait was slow and unsteady, and there was weakness of both lower extremities. There was no definite sensory change except the loss of vibration sensation in both feet. Deep tendon reflexes of the lower limbs were all exaggerated.

Laboratory findings were noncontributory.

Roentgenograms revealed a marked deformity of the posterior portion of the right 7th and 8th ribs. There was great expansion of the shafts of the bones and marked thinning of the cortices, with areas of translucence suggesting irregular cyst formation. There was an irregular wavy coarse trabeculation within the expanded bone, and a kidney-shaped mass with calcific margins extended into the soft tissue of the lateral thoracic wall. There were similar changes in the left 7th rib posteriorly, and in the bodies and arches of the 7th and 8th dorsal vertebrae. There was anterior and lateral compression of these vertebral bodies, and narrowing of the 6th and 7th interspaces. The expanded portion of the posterior inferior margin of the 7th dorsal body encroached considerably into the spinal canal (Fig. 5).

Lumbar puncture yielded CSF containing 96 mg. per cent total protein. Complete block was demonstrated on manometric test.

*Course.* Two weeks after admission, the pain in her back suddenly became worse, and the weakness of both legs increased. Babinski sign and ankle clonus were elicited on both sides. A zone of hypalgesia was found at the level of D6 and D7. Deep sensation was absent in both lower limbs from below the iliac crests.

*1st Operation.* On the 17th hospital day, a laminectomy of D5, 6, 7 vertebrae was performed by Dr. Ira Cohen. Fibrous tissue was seen within the laminal arches

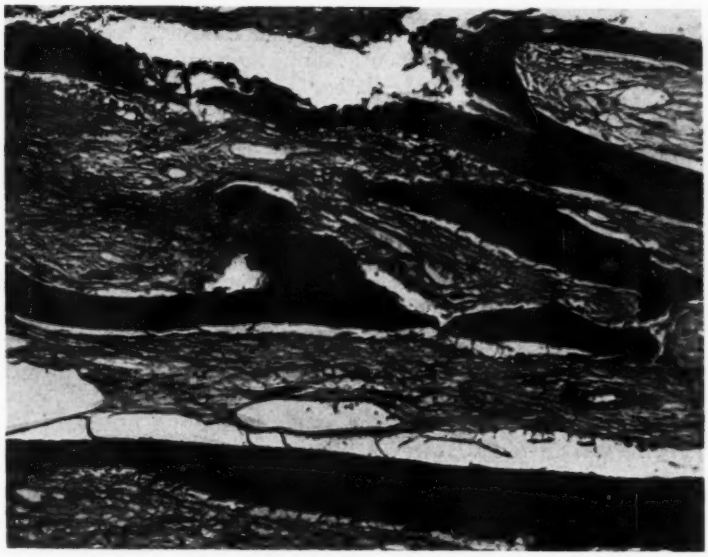

FIG. 6. *Case 4.* Polyostotic fibrous dysplasia. Section of bone removed from lamina. Trabeculae of metaplastic bone are developing in connective tissue. Hematoxylin-eosin stain, ×100.

of D5 and D6. An irregular-shaped extradural tumor, $\frac{1}{2} \times 1\frac{1}{2}$ inches in size, was removed from D5 and D6 portion of the spinal canal.

*Course.* Two weeks after operation, the abnormal findings had disappeared and the patient was wearing a brace and walking with a normal gait.

Fifteen months after discharge, paraplegia suddenly developed and she was re-admitted.

*2nd Operation.* The spinal canal from D4 to D7 was re-explored and an extradural tumor was removed from D4.

*Course.* The patient made a slowly progressive recovery and, 6 weeks later, she again was able to walk with support. She was seen 1 year later at the follow-up clinic, walking without difficulty. In 1949 she was admitted to the medical service on three occasions because of hypertensive cardiac failure. However, repeated neurological examinations revealed no abnormalities.

*Pathological Diagnosis.* Polyostotic fibrous dysplasia (Fig. 6).

*Comment.* The bone involvement in Case 4 was bilateral, multiple, extensive and included the vertebrae. The diseased tissue protruded into the

spinal canal from the affected vertebrae and encroached upon the spinal cord, which had been already embarrassed by the angulation of the spine caused by collapse of the vertebrae. Laminectomy and removal of the epidural portion of the dysplastic tissue rapidly and completely restored the motor power of both lower extremities. A similar but slower result was obtained by the second laminectomy which was done because of recurrence of symptoms.

Unlike osteitis deformans, fibrous dysplasia appears to be a congenital disorder of the bone-forming mesenchyme. It usually affects children or adolescents, and females more than males. It is a rare disease, characterized by bone changes, cutaneous pigmentation and sexual precocity. It was first described by Albright and his associates.[1] The disease has a tendency to involve bones of one side of the body. When more than one bone is involved, it is called "polyostotic fibrous dysplasia." If the change is limited to only one bone it is known as "monostotic fibrous dysplasia."

Ostotic fibrous dysplasia involves usually the diaphysis or metaphysis of the long bones and rarely occurs in the epiphysis. The bones most frequently involved are the femur, tibia, humerus and radius. Similar to osteitis deformans, it causes bending deformities. The affected area of the bone is cystic in appearance and contains giant-cells, and abundant fibrous and cartilaginous tissues.

In 1942 Lichtenstein and Jaffe[18] reviewed 90 cases of fibrous dysplasia. In only 1 patient were the vertebrae involved. Schlumberger[25] studied 67 cases of fibrous dysplasia involving a single bone, and in only 1 case the cervical spine was affected. However, in neither was there evidence of spinal cord compression.

## SUMMARY

1. One case of Paget's disease of the vertebrae with spinal cord compression at D1 and D2 is presented. Laminectomy benefited the patient.

2. Two cases of giant-cell tumor of the vertebra are reported, one with involvement of the cauda equina, and the other with cord compression. Laminectomy resulted in complete recovery of both patients.

3. One case of polyostotic fibrous dysplasia involving the dorsal spine with paraplegia is presented. The patient recovered after laminectomy.

4. The related literature of the aforementioned 3 conditions has been reviewed.

## REFERENCES

1. Albright, F., Butler, A. M., Hampton, A. O., and Smith, P. Syndrome characterized by osteitis fibrosa disseminata, areas of pigmentation and endocrine dysfunction, with precocious puberty in females. Report of five cases. *New Engl. J. Med.*, 1937, *216:* 727–746.
2. Alessi, D. Compressione midollare in un caso di malattia di Paget (nota clinica). *Rif. med.*, 1938, *54:* 538–544.
3. Ardin-Delteil, Azoulay, R., and Lagrot. Maladie osseuse de Paget et paraplégie hyperspasmodique en flexion. *Bull. Soc. méd. Hôp. Paris*, 1923, *47:* 920–924.
4. Brock, E. H., and Bogart, F. B. Benign giant cell tumor of the spine. Report of a case occurring in the cervical spine. *Amer. J. Roentgenol.*, 1945, *54:* 512–518.

5. COLCLOUGH, J. A. Compression of the spinal cord by osteitis deformans. Report of a case. *Surgery*, 1949, *25:* 760–765.
6. COLEY, B. L. Neoplasms of bone and related conditions. Their etiology, pathogenesis, diagnosis and treatment. *New York: P. B. Hoeber Inc.*, 1949, xiv, 765 pp.
7. COURVILLE, C. B., and LANGMADE, C. F. The significance of neurologic and psychiatric manifestations in the presence of Paget's disease of the skull. *Bull. Los Angeles neurol. Soc.*, 1947, *12:* 111–138.
8. ELKINGTON, J. ST.C. Paget's disease with paraplegia. *Proc. roy. Soc. Med.*, 1939, *32:* 1420–1421.
9. GARCIN, R., VARAY, A., and DIMO, H. Effondrement vertébral aigu au cours d'une maladie osseuse de Paget. Quadriplégie transitoire. Syndrome de Brown-Séquard, résiduel (contribution à l'étude des complications médullaires de la maladie de Paget). *Rev. neurol.*, 1937, *67:* 761–769.
10. GROSS, S. W. Compression of the spinal cord in Paget's disease of the vertebrae. *Amer. J. Surg.*, 1942, n.s. *55:* 575–577.
11. GUTMAN, A. B., and KASABACH, H. Paget's disease (osteitis deformans). Analysis of 116 cases. *Amer. J. med. Sci.*, 1936, n.s. *191:* 361–380.
12. HAGUENAU, J., and SICARD, A. Compression médullaire au cours de la maladie de Paget. *Rev. neurol.*, 1937, *68:* 846–849.
13. HILLMAN, R. W. Compression of the spinal cord in Paget's disease. *Brooklyn Hosp. J.*, 1941, *3:* 155–162.
14. KAPLAN, A. Acute spinal cord compression following hemorrhage within extradural neoplasm. Report of two cases with recovery. *Amer. J. Surg.*, 1942, n.s. *57:* 450–456.
15. KAY, H. D., SIMPSON, S. L., RIDDOCH, G., and VILVANDRÉ, G. E. Osteitis deformans. *Arch. intern. Med.*, 1934, *53:* 208–248.
16. KOLODNY, A. Bone sarcoma. The primary malignant tumors of bone and the giant cell tumor. *Surg. Gynec. Obstet.*, 1927, *44*, suppl. 1: ix, 214 pp.
17. LEWIS, D. Primary giant cell tumors of the vertebrae. Analysis of a group of cases, with report of case in which patient is well two years and nine months after operation. *J. Amer. med. Ass.*, 1924, *83:* 1224–1229.
18. LICHTENSTEIN, L., and JAFFE, H. L. Fibrous dysplasia of bone. A condition affecting one, several or many bones, the graver cases of which may present abnormal pigmentation of skin, premature sexual development, hyperthyroidism or still other extraskeletal abnormalities. *Arch. Path.*, 1942, *33:* 777–816.
19. MEYERDING, H. W. Benign and malignant giant-cell tumors of bone. Diagnosis and result of treatment. *J. Amer. med. Ass.*, 1941, *117:* 1849–1854.
20. PAGET, J. On a form of chronic inflammation of bones (osteitis deformans). *Med.-chir. Trans.*, 1877, *60:* 37–63. Reprinted in: *Med. Classics*, 1936, *1:* 29–53.
21. PETERSMA, J. P. Dwarslaesie van het ruggemerg bij ziekte van Paget. *Ned. Tijdschr. Geneesk.*, 1938, *82:* 3572–3575.
22. PETIT-DUTAILLIS, D., MARCHAND, J., and CALDERON, G. Un cas de compression médullaire par maladie osseuse de Paget grandement amélioré par la laminectomie. *Rev. neurol.*, 1936, *66:*71–78.
23. RABINER, A. M., and HAND, M. H. Paget's disease and the central nervous system. *N. Y. St. J. Med.*, 1947, *47:* 2689–2693.
24. SANTOS, J. V. Giant cell tumor of the spine. *Ann. Surg.*, 1930, *91:* 37–43.
25. SCHLUMBERGER, H. G. Fibrous dysplasia of single bones (monostotic fibrous dysplasia). *Milit. Surg.*, 1946, *99:* 504–527.
26. SCHMORL, G. Über ostitis deformans Paget. *Virchows Arch.*, 1932, *283:* 694–751.
27. SCHWARZ, G. A., and REBACK, S. Compression of the spinal cord in osteitis deformans (Paget's disease) of the vertebrae. *Amer. J. Roentgenol.*, 1939, *42:* 345–366.
28. TURNER, J. W. A. The spinal complications of Paget's disease (osteitis deformans). *Brain*, 1940, *63:* 321–349.
29. VERBIEST, H. Le traitement neurochirurgical des tumeurs bénignes des corps vertébraux avec compression de la moelle. *Rev. neurol.*, 1947, *79:* 528–535.
30. VINCENT, C., LANGERON, L., DEREUX, J., and LEMAITRE, L. Maladie osseuse de Paget. Installation progressive de signes de compression médullaire grave. Décompression opératoire avec restauration de l'état antérieur. *Rev. neurol.*, 1936, *65:* 794–799.
31. WHALLEY, N. Paget's disease of atlas and axis. *J. Neurol. Neurosurg. Psychiat.*, 1946, n.s. *9:* 84–86.
32. WYLLIE, W. G. The occurrence in osteitis deformans of lesions of the central nervous system, with a report of four cases. *Brain*, 1923, *46:* 336–351.

# THE DANGER OF AIR EMBOLISM WHEN REMOVING MENINGIOMAS ARISING ALONG THE SUPERIOR SAGITTAL OR LONGITUDINAL SINUS

## A METHOD OF PREVENTION

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MARTLAND,[7] Chief Medical Examiner of Essex County, New Jersey, stated in 1945:

Precautions should be taken in operations around the large veins of the neck, upper chest, mediastinum and dural sinuses to prevent air embolism as a complication. . . . Wounds or operations in which the dural sinuses are injured may cause air embolism. The walls of these sinuses are stiff, therefore, do not collapse easily and favor the entrance of air.

Neurosurgeons may fail to recognize this possibility. In Cushing and Eisenhardt's[1] book on meningiomas the only mention of possible air embolism is on page 498:

. . . regarding the consequences of excising the sagittal sinus . . . many of these early operations were critical enough as they stood without this added risk. Such handling and tugging of sinus and falx as were necessary for their partial resection was known to be a painful and often shock-producing procedure and not a step to be added to an already critical operation unless clearly necessary.

Dandy[3] in his chapter on surgery of the brain (page 516), stated of dural endothelioma:

For the large bony growths that bulge externally along the midline and incorporate the longitudinal sinus, a special type of operation is needed and is usually of such magnitude that the two-stage performance will probably be necessary. . . . This is almost the only tumor that now requires two stages. At the first stage the entire affected area of bone is removed in a more or less circular fashion. At the next stage the underlying area of dura is incised and reflected to the midline from each side. Then the longitudinal sinus is clamped, divided and sutured at each end and the incision carried down the falx. . . .

In none of Cushing's[1] 4 cases or Dandy's[2] 4 cases of dural meningiomas involving the longitudinal sinus was there any difficulty from air embolism although in most of the cases the sinus was found obliterated.

Poppen[8] in 1939 presented operative technics for removal of parasagittal meningiomas and mentioned separating the bony button with its enostosis overlying the tumor with a periosteal elevator but gave no warning of air embolism.

Jaeger[4] in 1942 discussed the ligation and resection of the superior longitudinal sinus and in recent reports[5,6] still made no reference to the possibility of air embolism.

A fatal case of air embolism from removal of a bone flap involving a meningioma along the longitudinal sinus and 3 successful removals of meningiomas similarly situated and involving the sinus without air serve as the basis of this report.

*Case 1.* #208610. Mrs. J.M., aged 56, was admitted to the medical service on Oct. 1, 1941 because of convulsions for the past 5 years. There had been an aura of a weak feeling in the stomach but the attacks were not focal in character. Dilantin and sedation had controlled the seizures fairly well but for the last 3 months 4 or 5 attacks a day had developed and vertigo, ataxia and occasional diplopia had

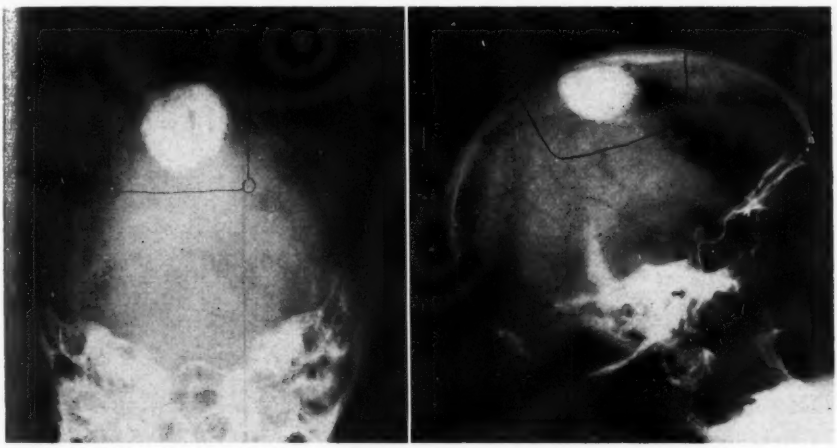


FIG. 1. *Case 1.* Roentgenograms showing the calcified meningioma in the vertex with an outline of the bone flap.

appeared. She had complained of an occasional numbness in the left forearm and hand. Memory defects and childish reactions had been noted by her children. There had been no headache or vomiting.

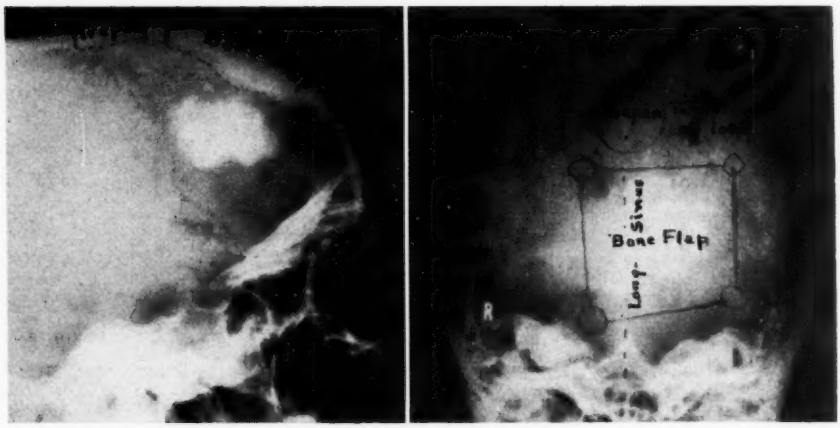
*Examination.* Her gait was ataxic with a positive Romberg. The left leg and arm were weaker than the right. Sensation was normal. The reflexes were very active; the left knee jerk was more active than the right. The cranial nerves were not involved and the eyegrounds appeared normal. B.P. was 175/106. The pressure and dynamics on lumbar puncture were normal, with 22.5 mg. per cent protein. Roentgenograms showed a large area of calcification, measuring 4 cm. in diameter, situated in the vertex mainly to the left of the midline and just behind the frontal suture. Increased vascularity of the skull was noted just to the right of the midline and immediately in front of the coronal suture. Because of the changes seen in the right frontal bone, and in the bone on the right and left in front of and behind the coronal suture, a large meningioma producing calcification in only a portion of the tumor was suspected (Fig. 1). EEG on October 14 was suggestive of an intracranial lesion located behind the coronal suture to the left of the midline.

*Operation.* Shortly after the bone flap was lifted from its irregular bony attachment to the longitudinal sinus the patient's blood pressure dropped from 130/100 to zero. Ten per cent glucose, citrated blood, plasma, intracardiac epinephrine, and artificial respiration with oxygen failed.

The cause of death was air embolism generalized in the right ventricle of the heart, in the coronary artery and in the omental vessels.

It seemed probable that the to-and-fro motion of the periosteal elevator used to free the bone flap from the longitudinal sinus had permitted aspiration of air with fatal result.

*Case 2.* #209613. Mrs. F.G., aged 56, was admitted on Nov. 16, 1941, with the history that in April 1940 she had 13 generalized convulsions in one day. Pneumonia




FIGS. 2 and 3. *Case 2.* Roentgenograms showing (left) calcified meningioma in vault of skull with outline of trepan and bone flap, and (right) outline of the button of bone removed by trepan for application of arterial clamp to the longitudinal sinus.

developed and on recovery a hysterectomy was performed. She was active and had no seizures until 3 weeks before admission, when another series of convulsions occurred in one day. She had noticed numbness in the right arm and 3 days before admission complained of sharp pains in the right shoulder.

*Examination.* The only neurological finding was a weakness of the left arm and forearm, with reflexes active and equal.

Roentgenograms showed a 3 by 4 cm. calcified mass in the frontal region, just to the left of the midline, which appeared to be attached to the calvarium. The inner table of the skull was irregular at this location although there was little vascular disturbance about it. Impression: Meningioma involving the vault of the skull.

*Operation.* With a trephine, a 2.5 cm. button of bone was first removed over the longitudinal sinus posterior to the contemplated bone flap (Figs. 2 and 3). The dura was incised for 1 cm. to either side and parallel to the longitudinal sinus, which was then temporarily occluded by a rubber-shod arterial clamp until removal of the tumor had been completed (Fig. 4).

*Course.* Convalescence was uneventful and the patient was dismissed 2 weeks after operation.

A similarly situated tumor with irregularity of the inner table was again encountered recently (1950). Air embolism, when freeing the bone flap from the longitudinal sinus, was undoubtedly prevented by the precaution of again temporarily occluding the sinus after trephination of a button of bone posterior to the bone flap.

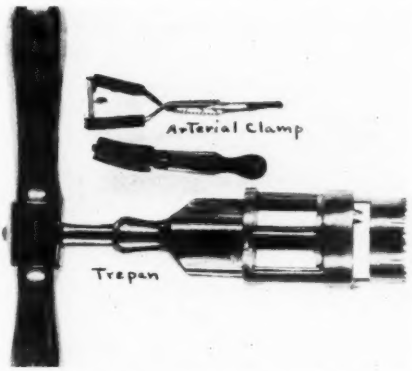



FIG. 4. Photograph of trepan and of arterial "bull dog" clamp used to expose and temporarily occlude longitudinal sinus before attempting elevation of the bone flap.

## CONCLUSIONS

Parasagittal meningiomas may cause irregularity of the inner table of the skull overlying the longitudinal sinus.

In these cases the to-and-fro motions of a periosteal elevator over the longitudinal sinus can facilitate the entrance of air with fatal emboli.

Air embolism was undoubtedly prevented in 3 other patients whose tumors were similarly situated.

The procedure was first to expose the longitudinal sinus posterior to the contemplated bone flap by trephination.

After trephination the dura was incised on either side of the sinus to permit the application of a rubber-shod "bulldog" arterial clamp, with occlusion of the sinus prior to the lifting of the bone flap.

## REFERENCES

1. CUSHING, H., and EISENHARDT, L. Meningiomas. Their classification, regional behaviour, life history, and surgical end results. *Springfield, Ill.: Charles C Thomas*, 1938, xiv, 785 pp.
2. DANDY, W. E. Removal of longitudinal sinus involved in tumors. *Arch. Surg., Chicago*, 1940, *41:* 244–256.
3. DANDY, W. E. Surgery of the brain. *Hagerstown, Md.: W. F. Prior Co., Inc.*, 1945, 671+17 pp. (see p. 516).
4. JAEGER, J. R. Ligation and resection of the superior longitudinal sinus. *Arch. Neurol. Psychiat., Chicago*, 1942, *48:* 977–986.
5. JAEGER, J. R. Resection of the superior longitudinal sinus. *Arch. Neurol. Psychiat., Chicago*, 1946, *55:* 74–75.
6. JAEGER, R. Observations on resection of the superior longitudinal sinus at and posterior to the rolandic venous inflow. *J. Neurosurg.*, 1951, *8:* 103–109.
7. MARTLAND, H. S. Air embolism. With special reference to its surgical importance. *Amer. J. Surg*, 1945, n.s. *68:* 281–286.
8. POPPEN, J. L. Parasagittal meningiomas: operative technique suggested for exposure. *Surg. Gynec. Obstet*, 1939, *68:* 957–959.

# THE TREATMENT OF BULLOUS KERATITIS BY GREATER SUPERFICIAL PETROSAL NEURECTOMY*

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While an exposition on bullous keratitis by a neurological surgeon may seem inappropriate, it may better serve our purpose to stress those features that are of greater concern to the neurosurgeon than the ophthalmologist in whose hands the diagnosis primarily rests.

Any discussion of bullous keratitis is necessarily a discussion of corneal edema and the mechanism of its production. As the name implies, bullous keratitis is the term applied to the most severe grade of corneal edema wherein the epithelium is separated from Bowman's membrane by a collection of fluid. A rather pendulous type of bulla may be formed, usually below the center of the cornea. The bulla is termed pendulous since the subepithelial collection of fluid can be moved about by pressure upon the eyelid.

The onset of the condition may be quite abrupt, occurring after only several hours of local discomfort. However, it may follow after several days of corneal edema.[11] The patient complains of pain, photophobia, lacrimation, and blurring of vision. The eye appears irritated and red. The symptoms become progressively severe until the bullae rupture. Healing is accomplished by such regeneration of the corneal epithelium as might occur after an ordinary corneal abrasion. Bullae are reformed only to break down again. However, the condition may progress to so severe a degree, with such intense pain from the formation and subsequent rupture of the bullae, that only enucleation remains as a means of relieving the patient of his misery.

Before entering into a discussion of corneal edema and the mechanism of its production, it might be well to recall that the transparent cornea consists of five strata from front to back:

1. The corneal epithelium.
2. Anterior elastic lamina (Bowman's membrane).
3. The corneal stroma.
4. The posterior elastic lamina (Descemet's membrane).
5. The endothelium of the anterior chamber.

The experimental work of Cogan and Kinsey[7] has resulted in a theory, which is at once reasonable and lucid, concerning the movement of the fluid within the cornea. The fluid is believed to enter the stroma at the limbus and

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o diffuse at all levels toward the center of the cornea. The greatest movement occurs at the corneal periphery, the least at the center. These authors howed that the epithelium and endothelium are impermeable to sodium hloride and function as semipermeable membranes. The corneal stroma, in ffect, is sandwiched between two semipermeable membranes—one on its nterior and the other on its posterior surface. The stroma, being permeable o sodium chloride, is unable to function as a semipermeable membrane at ll. Since the fluid within the stroma will eventually diffuse to the endohelial or epithelial surfaces, the electrolytes will be retained within the ornea while the water will be lost continuously into the hypertonic fluid ver the corneal surface. The evaporation taking place from this surface gain raises the local osmotic pressure, enabling the process to continue.

Cogan[4,5,6,9] also showed that the corneal epithelium could not be separated from Bowman's membrane, as in bullous keratitis, by forcing fluid nto the cornea from the aqueous. This could be done only by the absorption f a fluid from the outside by a cornea that was hypertonic to the precorneal ilm. It becomes apparent that if the tears have an inherently lower osmotic ension than the cornea, or if the osmotic tension of the cornea is unduly ncreased, as by damage to the endothelium, epithelial vesicles or bullae ould be formed by the imbibition of the excessive fluid. It follows, then, that increasing the tonicity of the tears, or other fluid in contact with the corneal surface, should promptly withdraw the water from the bulla or vesicle. That this occurs is attested to by the use of glycerin drops, contact lens with hypertonic solution, or the air-tight calcium chloride goggles used by Cogan, with good but transient success.

Conversely, as the bullae rupture, a further irritation results in an increased epiphora with a further dilution of the salt content in the precorneal mucous film and the subsequent lowering of tonicity. The lowered osmotic tension results in the formation of more bullae. When the eyes are closed at night and evaporation is prevented, dilution of the precorneal film occurs with the same unfortunate result.

It appeared advisable to direct our attention to the inhibition of lacrimation. Since local extirpation, diathermia, and x-ray treatment of the lacrimal gland had been used unsuccessfully (personal experience-L.V.J.) another approach was considered advisable.

It occurred to one of us (W.A.N.) that denervation of the lacrimal gland could be effectively accomplished by sectioning the greater superficial petrosal nerve. By denervation of the gland one could avoid such failure as might be attributed to accessory lacrimal tissue, after attempted extirpation, or to the incomplete ablation of glandular tissue following other types of therapy.

Originating at the genu of the facial nerve within the facial canal of the petrous bone, the greater superficial petrosal nerve emerges into the middle fossa through the hiatus canalis facialis, i.e. hiatus Fallopii. The nerve lies in a groove as it courses anteromedially and inferiorly across the petrous

portion of the temporal bone toward the lateral aspect of the internal carotid artery. This locus is reached under cover of the Gasserian ganglion or the mandibular nerve (Fig. 1). At this point it joins with the deep petrosal, a sympathetic nerve from the carotid plexus, to form the Vidian nerve, which terminates in the sphenopalatine ganglion. Fibers reach the lacrimal gland through the lacrimal branch of the ophthalmic nerve after passing along the zygomatic.

The excellent work of Chorobski and Penfield,[3] while largely concerned with cerebral vasodilator nerves, clearly demonstrated that secretory fibers enter the greater superficial petrosal nerve to supply the lacrimal gland. These fibers are preganglionic in type, and by virtue of stimulation studies are parasympathetic in action.

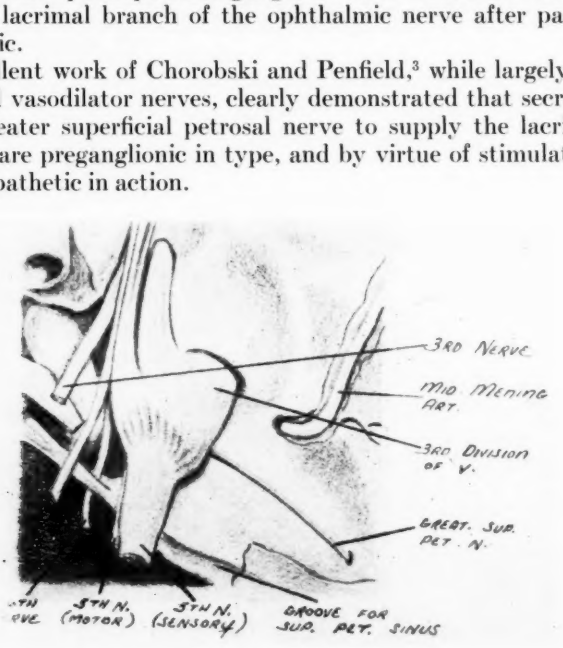


FIG. 1.

It was believed that the intracranial section of the greater superficial petrosal nerve would, by curtailing the production of tears, prevent the dilution of the precorneal film. Osmotic tension relations more favorable to the absorption of fluid from the bullae could thus be established. Accordingly this operation was done as an alternate procedure when such a patient with severe bullous keratitis was being considered for enucleation to relieve his pain.

The surgical approach to the greater superficial petrosal nerve is essentially the same as that used in the extradural temporal approach to the sensory root of the fifth nerve.

With the patient in the sitting position, he is prepared and draped for a temporal operation. The usual anesthesia is a combination of a light maintenance level of Pentothal and adequate procaine infiltration of the incision line. A vertical incision is made 1 to 2 cm. anterior to the ear, perpendicular to and based upon the zygomatic process of the temporal bone. The temporalis muscle is split in the direction

of its fibers, and an opening about 3 cm. in diameter is made in the temporal bone as close to the floor of the middle fossa as possible. The dura is stripped from the floor of the middle fossa, progressing medially until the middle meningeal artery is encountered. At this point the approach is angled sharply in a posterior direction. It is usually unnecessary to divide the middle meningeal artery. The dissection is carried up the anterior surface of the petrous bone until the dura seems more tightly adherent to the floor.

This frequently marks the groove of the greater superficial petrosal nerve. It may be necessary to proceed with sharp dissection, since the nerve is often quite adherent to the dura. The nerve is preferably allowed to remain undisturbed in its groove and is followed laterally to the hiatus Fallopii and medially to the point of its disappearance behind the Gasserian ganglion or the mandibular division of the trigeminal nerve. Mild electrical stimulation near the hiatus will cause facial movement and is apparently painful under light anesthesia. Care should be taken to avoid mistaking the lesser superficial petrosal nerve for the greater, the lesser being a smaller, more inferiorly placed nerve which is encountered infrequently.

When the greater superficial petrosal nerve has been satisfactorily identified, it is divided within its groove with a sharp knife-point, to avoid any damage to the facial nerve by traction. A small section of the distal end of the nerve is taken for histological confirmation of nerve tissue. The central end of the nerve is gently elevated from the groove and a metal clip applied. The distal end is usually long enough to permit a doubling back upon itself and the application of clips, in the effort to discourage any regenerating fibers from seeking this outlet. There is very little bleeding and no loss of cerebrospinal fluid unless the dura has been inadvertently torn. When the retractor is removed the dura reexpands and the incision is closed in the routine fashion.

The patients are usually ambulant on the 1st or 2nd postoperative day and are ready to leave on the 4th or 5th.

There is an immediate decrease in the ocular pain as well as in lacrimation as evidenced by the Schirmer test. The corneal bleb formations, i.e. bullae, and edema subside in the next several days, as does the angry redness which was a prominent feature pre-operatively. As the healing of the residual corneal abrasions proceeds in the usual fashion, the vision begins to improve. In 2 of our patients the visual acuity in the affected eye was 20/300 before operation and 20/30 four weeks after, with only a mild degree of irritative conjunctival injection remaining. Where corneal opacity remains because of necrotic epithelium, secondary corneal stripping may be necessary to gain maximal visual acuity even after the establishment of favorable osmotic tension relations.

In a previous publication,[10] we have stressed that a vicious cycle of osmotic hypotonicity is established when the rupture of a bulla, i.e. the resulting corneal abrasion, acting as a powerful stimulant for tear formation, causes a further dilution of the salt content in the precorneal film, with the inevitable production of more bullae. The cycle is interrupted by eliminating the serous component of the tears and leaving only the precorneal mucous film of higher electrolyte content to effect the withdrawal of the fluid from the bullae. There has been no suggestion of keratitis sicca in any of the 6 pa-

tients who had been operated upon in the period from at least 6 months to nearly 2 years previously. There was one failure, purely technical, in which the nerve was mis-identified and escaped section. At reoperation the intact nerve was divided and the patient relieved completely. Some return of tear function was noted by Gardner *et al.*[8] in 6 of 31 patients in whom the production of a "dry" eye was incidental to the neurectomy done for the relief of unilateral headache. This same author (with Boyer[1]), reporting on the surgical treatment of crocodile tears by section of the greater superficial petrosal nerve in 3 cases, had a recurrence of tear function in 2.

The lesser superficial petrosal apparently had been inadvertently divided when the greater superficial petrosal nerve was sectioned. It was believed that parotid gland fibers in the lesser superficial petrosal nerve had, by mis-direction, grown into the peripheral end of the latter. Lacrimation was again eliminated by the intracranial section of the ninth nerve.

Chorobski,[2] writing on the syndrome of crocodile tears, questions the accepted hypothesis of such mis-direction of regenerating axons as an explanation for paroxysmal lacrimation. He offers the concept of "cross-stimulation" between the inadequately insulated autonomic components of the facial nerve or between these and the afferent nerve fibers.

We have, to date, observed no evidence of recurrence of lacrimation in any of those patients who had been operated upon for longer than 6 months. Likewise, they have remained pain-free and grateful that enucleation was unnecessary.

As long as the precorneal film is not so excessively diluted by tears that it becomes hypotonic to the corneal stroma, there will be no reformation of the bullae—the ultimate criterion for judging the efficacy and rationale of this procedure.

## CONCLUSIONS

1. Greater superficial petrosal neurectomy has been effective in relieving the symptoms and signs of severe chronic bullous keratitis, by the restoration of a more physiologic osmotic tension relation between the precorneal film and the corneal stroma.

## REFERENCES

1. Boyer, F. C., and Gardner, W. J. Paroxysmal lacrimation (syndrome of crocodile tears) and its surgical treatment. Relation to auriculotemporal syndrome. *Arch. Neurol. Psychiat., Chicago,* 1949, *61:* 56–64.
2. Chorobski, J. The syndrome of crocodile tears. *Arch. Neurol. Psychiat., Chicago,* 1951, *65:* 299–318.
3. Chorobski, J., and Penfield, W. Cerebral vasodilator nerves and their pathway from the medulla oblongata. With observations on the pial and intracerebral vascular plexus. *Arch. Neurol. Psychiat., Chicago,* 1932, *28:* 1257–1289.
4. Cogan, D. G. Some practical considerations pertaining to corneal edema. *Arch. Ophthal., N. Y.* 1941, *25:* 552–556.
5. Cogan, D. G., Hirsch, E. O., and Kinsey, V. E. The cornea. VI. Permeability characteristics of the excised cornea. *Arch. Ophthal., N. Y.,* 1944, *31:* 408–412.
6. Cogan, D. G., and Kinsey, V. E. The cornea. I. Transfer of water and sodium chloride by osmosis and diffusion through the excised cornea. *Arch. Ophthal., N. Y.,* 1942, *27:* 466–476.

7. COGAN, D. G., and KINSEY, V. E. The cornea. V. Physiologic aspects. *Arch. Ophthal., N. Y.*, 1942, *28:* 661–669.
8. GARDNER, W. J., STOWELL, A., and DUTLINGER, R. Resection of the greater superficial petrosal nerve in the treatment of unilateral headache. *J. Neurosurg.*, 1947, *4:* 105–114.
9. HOLT, M., and COGAN, D. G. The cornea. VIII. Permeability of the excised cornea to ions, as determined by measurements of impedance. *Arch. Ophthal., N. Y.*, 1946, *35:* 292–298.
10. JOHNSON, L. V., and NOSIK, W. A. Greater superficial petrosal neurectomy for relief of chronic bullous keratitis. *Arch. Ophthal., N. Y.*, 1951, *45:* 32–37.
11. SIMPSON, G. V. Corneal edema. *Trans. Amer. ophthal. Soc.*, 1949, *47:* 692–737.

# LUMBAR AND SACRAL CYSTS CAUSING PAIN*

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(Received for publication May 3, 1951)

WE HAVE discovered in about 1 of each 100 patients operated upon after a diagnosis of low lumbar disc rupture a red herring consisting of a lumbar or sacral cyst. These cysts are fluid-filled swellings within the nerve[3] or arise from the dura[1] as meningoceles and compress a cauda or a nerve tract as it emerges from the dura. After Tarlov[3] described this lesion in 1948 we recognized its significance.

Our first experience with such a lesion occurred in 1942. The patient, a white female 58 years old, presented a typical history and signs of a lumbosacral disc rupture, with pain and hypesthesia in the area of distribution of the left 1st sacral nerve. Air myelograms were not helpful. At operation a herniated nucleus was not found, but a cystic swelling, 1.5 cm. in diameter, was uncovered in the 1st sacral nerve beneath the upper edge of the sacrum. The overlying sacrum was rongeured away but the mass was not disturbed. The patient was unrelieved of her discomfort.

In 1949 Dr. Frederick Fischer, the orthopedic surgeon, was doing a fusion on a patient with spondylolisthesis and called us into the operating room after the sacrum was exposed. Two areas of erosion in the left upper sacrum were seen overlying cysts in the 1st and 2nd sacral nerves. The cysts were about 1.5 and 2.5 cm. in diameter, respectively, and the overlying sacrum was paper-thin. The cysts were not molested but were left uncovered. The patient did not complain of immediate postoperative pain but died suddenly 1 month after operation, presumably from a pulmonary embolism.

The findings in 3 patients who came to exploratory surgery during 1950 we believe throw some light on the development of these sacral cysts. Whereas the cyst described by Tarlov[3] and those we saw earlier appeared smooth, as if of long standing, the findings in these patients suggested that the lesions were acute and had developed recently within a short period of time.

## REPORT OF CASES

*Case 1.* J. McG., a white male 42 years old, was a heavy, muscular foreman who had been troubled with recurrent back pains for a year. Five days prior to admission he had experienced excruciating pain in his back and left leg while bending over to feed his dog. The left ankle jerk was absent, raising the left leg was impossible because of pain, and hypesthesia was present over the left 1st sacral distribution. Because of the unremitting pain the lumbosacral space on the left was explored. A herniated nucleus was not found. However, the 5th lumbar lamina was markedly

* Presented at the meeting of the Harvey Cushing Society, Hollywood, Florida, April 28, 1951.

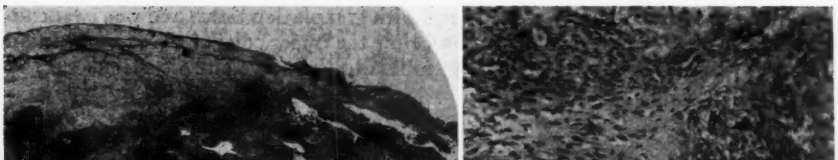
mobile. The 1st sacral nerve was covered with granulation tissue and was swollen to a diameter of 1.5 cm. at one point just below the upper edge of the sacrum. In appearance, the swelling suggested local trauma to the nerve and we speculated that such trauma could be associated with the abnormally mobile 5th lumbar lamina. The sacrum was unroofed over the bruised swelling in the nerve. The patient was advised to have a fusion but he was free of pain postoperatively and elected to wait.

*Case 2.* V. McC., a slight, athletic white female 46 years old, was admitted with a one-day history of severe low back and left leg pain. Since a fall while dancing in a night club some years previously, she had been troubled with episodes of moderate low back pain, although they had not been disabling. On examination lumbar tenderness was not present. Raising the *right* leg produced pain in the left buttock. Both

FIG. 1. *Case 2.* Myelogram showing almost complete block at 4th lumbar level.
FIG. 2. *Case 2.* Photograph of section of 5th lumbar nerve removed at operation.

ankle jerks were absent. There was hypesthesia over the 1st sacral distribution on the left. After 10 days of orthopedic observation, manipulation and traction, the pain increased in severity and myelograms were obtained (Fig. 1). The 4th and 5th laminae were removed and the dura was opened. A soft mass, about 1 inch in diameter, was found compressing the cauda extradurally in the 5th lumbar nerve. The nerve was sectioned above and below the swelling and the mass was removed (Fig. 2). The lesion was thought to be a neurofibroma, but on section it was found to consist of a hemorrhage into the nerve (Figs. 3 and 4). The patient was entirely relieved of her pain.

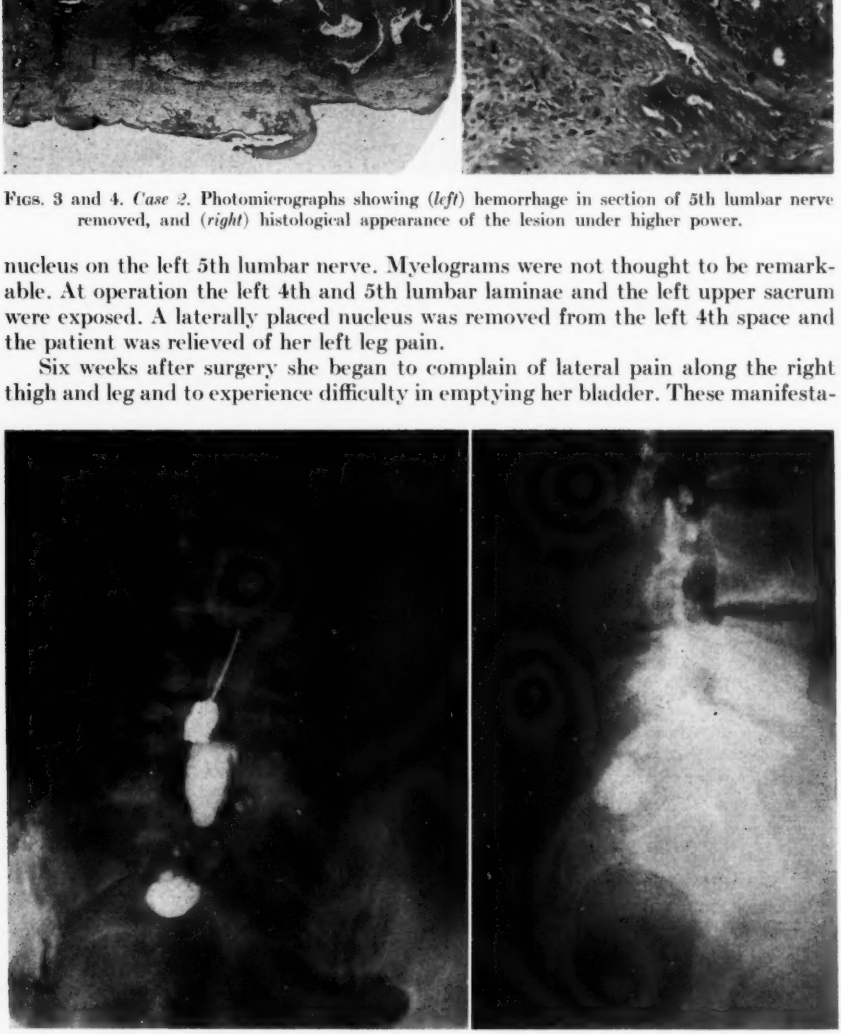
*Case 3.* R.C., a white female 48 years old, was first admitted with a history of back and left leg pain for over 20 years. Eighteen months previously she had been in an automobile collision, following which she was incapacitated by the low back and left leg pain. Neurological findings suggested an impingement of a herniated



FIGS. 3 and 4. *Case 2.* Photomicrographs showing (*left*) hemorrhage in section of 5th lumbar nerve removed, and (*right*) histological appearance of the lesion under higher power.

nucleus on the left 5th lumbar nerve. Myelograms were not thought to be remarkable. At operation the left 4th and 5th lumbar laminae and the left upper sacrum were exposed. A laterally placed nucleus was removed from the left 4th space and the patient was relieved of her left leg pain.

Six weeks after surgery she began to complain of lateral pain along the right thigh and leg and to experience difficulty in emptying her bladder. These manifesta-



FIGS. 5 and 6. *Case 3.* Roentgenograms at the time of first admission to hospital, showing (*left*) collection of pantopaque beneath upper sacrum on right side, and (*right*) intact appearance of sacrum over cyst.

ions became progressively more severe during the 12 months before she was re-dmitted. There had been complete urinary retention for the last 2 days.

Raising either leg produced pain. The knee and ankle jerks were normal. Aside rom an area of hypesthesia laterally on the right thigh, other sensory changes could ot be found. Myelograms (Figs. 5 and 6) of the lumbosacral spine revealed a collec-ion of pantopaque beneath the upper sacrum on the right side. The myelograms Fig. 7) obtained on the previous admission had shown this collection of pantopaque nd it appeared again on roentgeno-rams obtained some 3 months later. 'he sacrum overlying the pantopaque ollection was thinner than in the film aken a year earlier.

The right upper sacrum was ex-osed surgically, revealing a paper-thin ulging, 2.5 cm. in diameter, in the acrum about 2.5 cm. below its upper dge. A cyst, 3 cm. in diameter, was un-overed in the 2nd sacral nerve by re-noving the overlying sacrum. Small ncisions were made at the upper and ower ends of the cyst and its contents were irrigated with saline. The fluid was colorless, with flecks of panto-paque. The wall of the cyst was very hin, apparently consisting of neural issue and nerve sheath. Tissue was not removed for fear of further disturbing bladder function.

Postoperatively, relief of pain was immediate and bladder function re-turned promptly.

FIG. 7. *Case 3.* Roentgenogram showing erosion of sacrum over cyst during 14 months intervening from initial examination (Fig. 6).

Although the localized swelling in the 1st sacral nerve of Case 1 was not proved to be a cyst, we have the impression that local trauma may be the forerunner of such cysts. We feel that the lesion found in Case 2 may represent an intermediate stage in the formation of intraneural cysts. In Case 3, the marked erosion of the sacrum in the 14 months elapsing between lumbosacral roentgenograms implies some factor other than a congenital one in the production of such cysts, and the 3 cases suggest a progressive sequence: (1) Nerve trauma, (2) Intraneural hemorrhage, (3) Intraneural cyst.

One of the authors (F.S.) and Nielsen[2] reported another type of lumbar cyst which is epidural but communicates with the subarachnoid space and for which surgery had not been done previously.

A commoner lesion of this type occurs postoperatively. We have had experience on several occasions of inadvertently nicking the dura with the Kerrison rongeur without opening the arachnoid. The result has been an immediate bulging of the arachnoid through the dural defect and this would have remained as a meningocele if the dural defect had not been closed with a suture. It is our impression that if such a defect in the dura cannot be

sutured it would be best to incise the bulging arachnoid. Probably some of the instances of meningocele following hemilaminectomy which are reported as having been overlooked at the time of a nucleus pulposus removal are really postoperative, the dura or nerve sheath having been injured at the time of the first operation. The following case illustrates this situation.

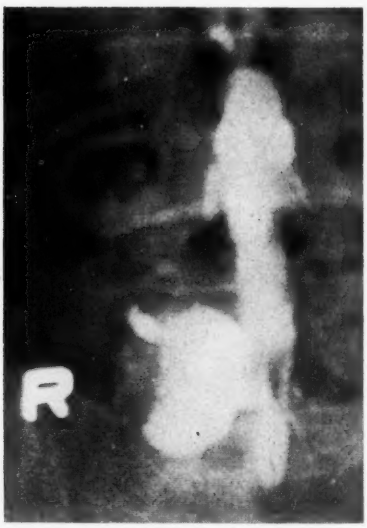



FIG. 8. *Case 4.* Postoperative lumbosacral cyst communicating with subarachnoid space.

*Case 4.* Z.V., a white male 30 years old, was admitted in September 1950 because of a dull ache in the right hip which had gradually become disabling during a period of a few weeks. In December 1947, a large herniated nucleus at the left lumbosacral space had been removed through a left-sided approach and the pain, sensory and reflex changes classical of 1st sacral nerve compression had entirely disappeared. In December 1949, signs of right 1st sacral nerve compression developed after the patient had lifted a bag of flour, and a herniated nucleus was removed from beneath the right sacral nerve. In teasing the nerve away from the underlying protrusion the nerve sheath had been torn, with escape of some spinal fluid. The man had been free from pain until the current admission.

Neurological examination revealed no sensory, motor or reflex changes. Myelograms (Fig. 8) revealed a collection of pantopaque in a cyst at the right lumbosacral level. The cyst could be emptied of pantopaque by changing the tilt of the table.

At operation a thin-walled cyst, 2.5 cm. in diameter, was found beneath the upper edge of the sacrum at the junction of the dura and the exit of the 1st sacral nerve. The small pedicle was ligated and the cyst removed in toto (Fig. 9). The histological characteristics of the cyst wall were those of a meningocele.

Pain has not recurred since operation.

The cyst in Case 4 was not present at the time of previous operation. No doubt the stage was set for the development of the cyst when the nerve sheath or dura was torn while teasing the nerve from the posterior ligament overlying the large herniated nucleus pulposus.

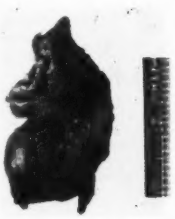


FIG. 9. *Case 4.* Postoperative epidural lumbosacral cyst.

## CONCLUSIONS

1. Perineural or epidural, lumbar or sacral cysts may be evidenced by symptoms similar to those produced by a herniated nucleus pulposus.

2. A post-traumatic or posteroperative etiology for such cysts is suggested.

## REFERENCES

1. Hyndman, O. R., and Gerber, W. F. Spinal extradural cysts, congenital and acquired. Report of cases. *J. Neurosurg.*, 1946, *3:* 474–486.
2. Schreiber, F., and Nielsen, A. Lumbar spinal extradural cyst. *Amer. J. Surg.*, 1950, n.s. *80:* 124–126.
3. Tarlov, I. M. Cysts (perineurial) of the sacral roots. Another cause (removable) of sciatic pain. *J. Amer. med. Ass.*, 1948, *138:* 740–744.
4. Winkler, H., and Powers, J. A. Meningocele following hemilaminectomy. A report of two cases. *N. Carolina med. J.*, 1950, *11:* 292–294.

# NOTES ON A SERIES OF BRAIN TUMORS

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FROM January 1, 1931 to January 1, 1941, 891 verified cases of brain tumor were catalogued in the Registry of the Department of Neurosurgery at the University and Graduate Hospitals. Eighty-nine of these tumors were verified at autopsy without previous operation, leaving a group of 802 cases in which surgery was performed. All of these patients have been adequately followed, due to the tireless efforts of Miss Anne Barnhart, R.N., who has charge of the Brain Tumor Registry. Now that we have a 10–20-year survival period in this group, a record of the results seems justified. In the past, the consequences of intracranial surgery of brain tumors have been based upon series of cases in which the operations were performed by a single, most skillful and experienced neurosurgeon, or his equally skillful and experienced assistant, Horrax. The reports of Van Wagenen,[7] Davidoff,[2] Cairns,[1] Henderson,[4] Oldberg,[6] and Eisenhardt[3] are all from Cushing's series. In our group, however, between 150 and 200 cases were allotted to the various senior residents who had completed two years of training. Furthermore, rather less attention has been paid to the immediate surgical mortality. Every reasonable attempt has always been made to extirpate a tumor in as complete a fashion as possible, without condemning the patient to a permanent and crippling neurologic deficit. Many of the patients recorded as having a recurrence died following a second operative intervention. Our interest lies in the final outcome, regardless of the number of operations.

Of the 802 patients operated upon between 1931 and 1941, 162, or 20 per cent, are alive in 1950. An additional 35 patients are known to have lived 10 years or longer and then died, 19 of intercurrent disease and 16 from recurrence of the tumor. Of the group of 802 patients, therefore, 197, or 24 per cent, lived for 10 years or more after the tumor was attacked. An additional 41 lived 5 years or more and died, 28 from recurrence, 13 from other disease. Among these 238 patients living 5 years or more 173, or 72 per cent, returned to work. In the entire series of 891 cases, 564, or 63 per cent, were dead within 5 years.

Horrax[5] has pointed out that the most favorable results following brain tumor surgery occur when the tumor exposed falls into one or the other of the following pathologic groups: meningioma, pituitary adenoma, cystic glioma or acoustic neuroma. In a number of instances, patients with the rarer

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types of intracranial lesions have shown 10–20-year survival periods. Our series of 197 cases in which the patients lived 10 years or longer includes 59 meningiomas (30 per cent), 44 pituitary adenomas (22 per cent), 39 gliomas (20 per cent), 13 hemangiomas (6 per cent), 9 craniopharyngiomas (4 per cent), 8 acoustic neuromas (4 per cent), 5 ependymomas (2 per cent), and 20 (12 per cent) in the miscellaneous group.

The astrocytomas, 143 cerebral and 84 cerebellar, total 227 cases, or 25.4 per cent of the entire series. The division as to position above or below the tentorium became necessary because the life expectancy in the two groups seems so different. Among the 143 patients with cerebral astrocytomas, 15, or 10.5 per cent, are alive in 1950, and 2 others lived over 10 years. Those with cerebellar astrocytomas numbered 84, and 18, or 21.7 per cent, are alive in 1950. In this group of 18 cerebellar astrocytomas, 14 were cystic and 4, solid tumors. The nubbin was removed from the cyst wall with prolonged recovery. The 4 solid tumors lay laterally in the cerebellar hemisphere so that amputation and complete removal were possible. No patient with a solid glioma of the vermis of the cerebellum lived over 5 years. In 2 additional cases of cerebellar astrocytoma, 1 solid and 1 cystic, the patients lived 11 years and died of recurrence. Of the 20 patients with cerebellar glioma surviving beyond the 10-year period, 18 returned to work.

In the 15 patients with cerebral astrocytomas who are alive in 1950 the tumors were located as follows: 7 temporal, 4 parietal, 3 frontal and 1 occipital, all in the right cerebral hemisphere in right-handed patients. Extensive resections were carried out with apparently complete removal in all but 1 case. In this instance there was a recurrence of a cystic astrocytoma in the right parietal region after 16 years. The patient was recently reoperated upon and he has been well and working for the past 27 months. Two additional patients with cerebral glioma lived over 10 years and died of intercurrent disease. Four lived over 5 years, 3 dying from recurrence, and 1 in an accident. In this group of 21 patients living 5 years or more, 13 were able to return to their work.

The meningiomas numbered 142, or 16 per cent of the total series of 891 brain tumors. Forty-seven of these patients are alive in 1950. Eighteen lived for over 15 years. Four of these are known to have died from intercurrent disease and 14 are alive. In the 10–15-year group of survivors, 41 in all, 7 are known dead from recurrence and 1 from intercurrent disease; 33 are alive and well. Among the 59 patients surviving 10 years or longer, 41 returned to work. In the 5–10-year group of 14 patients, 7 are dead from recurrence and 7 from intercurrent disease. Ten of these 14 were gainfully employed before they died.

The 142 glioblastomas (16 per cent) and 42 metastatic carcinomas (5 per cent) may be briefly described. No one of these patients lived into his 5th postoperative year and all died from recurrence.

In the group of 80 pituitary adenomas (9 per cent of the series), 55 chromophobe, 17 eosinophile and 8 mixed adenomas, 33 of the patients are

alive in 1950. An additional 11 lived 10 years or over. In this latter group, 8 died of intercurrent disease and 3 of recurrence. Altogether 21 patients lived 15 years or more. Four of these died of intercurrent disease, leaving 17 alive in 1950. Nine additional patients lived from 5 to 10 years, 6 dying of recurrence and 3 from intercurrent disease. Of the entire series, 53 lived over 5 years and 42 returned to work.

In the group of 50 medulloblastomas (6 per cent), 1 patient is alive and working in 1950. Another lived 11 years and died, probably from recurrence, although unfortunately without autopsy. Very heavy doses of irradiation therapy had been administered during at least five intensive courses of treatment. Three months prior to death no evidence of increased intracranial pressure was noted, although unsteadiness of gait was recorded. This patient worked within 9 months of her death. A third patient lived 7 years and died of a recurrence, working for 5 years of his postoperative period. At the time of the original operation, the patient who is still alive after 11 years was 10 years of age; the girl who survived 11 years was 15; and the 7-year survivor was 16. No patient in whom symptoms developed at the age of 7 years or younger survived beyond his 5th postoperative year in this group of tumors, in spite of vigorous surgical removal and intensive irradiation therapy.

There were 38 acoustic neuromas (4 per cent) verified in this series. Seven of the patients are alive in 1950. Another lived over 10 years and died from renal disease. Three lived over 5 years, all dying from recurrence. Fourteen lived into their 5th year and died, 12 of recurrence, 1 in an accident and 1 of cardiac disease. In no other group of cases is an attempt at total extirpation of the tumor more justified than in cases of acoustic neuroma. Recurrence and death are otherwise inevitable. Of the 11 patients surviving more than 5 years, 10 returned to work.

Among 33 cases of craniopharyngioma (3 per cent), 8 patients are alive in 1950. One other lived over 11 years, dying from intercurrent disease. Four of the 8 patients alive in 1950 have a survival period of 15 years or more. Four others lived 5 years or more, 3 dying of recurrence. Of the 13 surviving over 5 years, 10 returned to work.

There are 19 hemangiomas in this series, all subtentorial. Eleven of these patients are alive in 1950 and 2 others lived 10 years or more. This is by far the most hopeful record of any intracranial lesion. One additional patient lived over 5 years. Of these 14 living 5 years or more, 10 returned to work.

Of the 18 patients with ependymomas, 4 are alive in 1950. One, in addition, lived 15 years and died in an accident. Two of these 5 survivors were wage earners postoperatively.

The oligodendrogliomas total 14 cases, with no patient alive in 1950 and a single 14-year survival, death occurring from what was purported to be meningovascular syphilis. A second patient lived 5 years and died of intercurrent disease. Neither of these patients was able to return to work.

The miscellaneous groups comprise 86 patients. None of these groups

TABLE 1

| Verified Tumors Jan. 1931–Jan. 1941 | No. in 10 Yrs. | Alive 1950 | Lived 10 Yrs. or Over | Lived 5 Yrs. or Over | Lived Less than 5 Yrs. | Died Nonop. Autopsy |
|---|---|---|---|---|---|---|
| Astrocytomas | | | | | | |
| Cerebral | 143 | 15 | 2 | 4 | 105 | 17 |
| Cerebellar | 84 | 18 | 2 | 2 | 48 | 14 |
| Astrocytomas—total | 227 | 33 | 4 | 6 | 153 | 31 |
| Glioblastoma multiforme | 142 | 0 | 0 | 0 | 122 | 20 |
| Meningiomas | 142 | 47 | 12 | 14 | 65 | 4 |
| Pituitary adenomas | 80 | 33 | 11 | 9 | 26 | 1 |
| Medulloblastomas | 50 | 1 | 1 | 1 | 46 | 1 |
| Metastatic carcinomas | 42 | 0 | 0 | 0 | 35 | 7 |
| Acoustic neuromas | 38 | 7 | 1 | 3 | 26 | 1 |
| Craniopharyngiomas | 33 | 8 | 1 | 4 | 20 | 0 |
| Hemangiomas | 19 | 11 | 2 | 1 | 4 | 1 |
| Ependymomas | 18 | 4 | 1 | 0 | 11 | 2 |
| Oligodendrogliomas | 14 | 0 | 1 | 1 | 12 | 0 |
| Miscellaneous tumors | 86 | 18 | 1 | 2 | 44 | 21 |
| Verified tumors—total | 891 | 162 | 35 | 41 | 564 | 89 |

contains more than 12 examples. Of these 86 patients, 18 are alive in 1950. Of 10 with cholesteatomas, 5 are alive in 1950, while 4 lived less than 5 years. Of 9 with papillomas, 3 are alive in 1950; 1 lived over 5 years and 4, less than 5 years. Of 6 with osteomas, 5 are alive in 1950. Also alive in 1950 are 5 pa-

TABLE 2

| Miscellaneous tumors Jan. 1931–Jan. 1941 | No. in 10 Yrs. | Alive 1950 | Lived 10 Yrs. or Over | Lived 5 Yrs. or Over | Lived Less than 5 Yrs. | Died Nonop. Autopsy |
|---|---|---|---|---|---|---|
| Spongioblastomas unipolare | 12 | 1 | 0 | 0 | 4 | 7 |
| Astroblastomas | 11 | 0 | 0 | 0 | 7 | 2 |
| Cholesteatomas | 10 | 5 | 0 | 0 | 4 | 1 |
| Papillomas | 9 | 3 | 0 | 1 | 4 | 1 |
| Pinealomas | 8 | 0 | 0 | 0 | 5 | 3 |
| Tuberculomas | 6 | 1 | 0 | 0 | 3 | 2 |
| Osteomas | 6 | 5 | 0 | 0 | 1 | 0 |
| Neuroblastomas | 6 | 1 | 0 | 0 | 5 | 0 |
| Chondromas | 5 | 0 | 1 | 1 | 1 | 2 |
| Teratomas | 3 | 0 | 0 | 0 | 3 | 0 |
| Sarcomas | 3 | 0 | 0 | 0 | 3 | 0 |
| Gummas | 2 | 0 | 0 | 0 | 1 | 1 |
| Ganglioneuroma | 1 | 1 | 0 | 0 | 0 | 0 |
| Dermoid | 1 | 1 | 0 | 0 | 0 | 0 |
| Paraphysial cyst | 1 | 0 | 0 | 0 | 1 | 0 |
| Angiofibroma | 1 | 0 | 0 | 0 | 1 | 0 |
| Chordoma | 1 | 0 | 0 | 0 | 1 | 0 |
| Miscellaneous tumors—total | 86 | 18 | 1 | 2 | 44 | 21 |

tients whose tumors were verified respectively as: a spongioblastoma unipolare, a tuberculoma, a neuroblastoma, a ganglioneuroma and a dermoid, all with a survival period of 10 years or over. In a case of chondroma, the patient lived over 10 years and died of intercurrent disease. Among 11 cases of astroblastomas and 8 of pinealomas, no patient lived beyond the 4th postoperative year. Of the 18 survivors alive in 1950, 14 are working.

In reviewing this series of tumors, as far as the gliomas are concerned, the pathology and the position of the tumor, and more especially the pathology, determine the outcome. Solid gliomas present a fairly hopeless situation, unless they are so situated that a lobectomy can be performed, that is in the right frontal, right temporal, either occipital lobe or in either cerebellar hemisphere. The cystic gliomas, as has long been known, have a much better prognosis. The surgeon's luck in exposing a lesion of the proper type favorably placed is more important than his skill in handling gliomas. But the angle tumors, the meningiomas and the pituitary adenomas require both skill and experience, and some small element of luck as well. These are benign tumors, sometimes, unfortunately, very awkwardly situated, and if they can be completely removed or if a pituitary adenoma can be thoroughly gutted without damage to adjacent structures, they do not recur. It would seem from this review of a representative series that roughly 40 per cent of brain tumors are relatively benign. Careful surgery, in these groups particularly, should result in about 25 per cent 10-year-survival and a 70 per cent return to work, temporarily at least, in any large series of cases of this kind.

## REFERENCES

1. Cairns, H. The ultimate results of operations for intracranial tumours. A study of a series of cases after a nine-year interval. *Yale J. Biol. Med.*, 1936, *8:* 421–492.
2. Davidoff, L. M. A thirteen year follow-up study of a series of cases of verified tumors of the brain. *Arch. Neurol. Psychiat., Chicago*, 1940, *44:* 1246–1261.
3. Eisenhardt, L. Long postoperative survivals in cases of intracranial tumor. *Res. Publ. Ass. nerv. ment. Dis.*, 1937, *16:* 390–416.
4. Henderson, W. R. The pituitary adenomata. A follow-up study of the surgical results in 338 cases (Dr. Harvey Cushing's series). *Brit. J. Surg.*, 1939, *26:* 809–921.
5. Horrax, G. Favorable types of brain tumor and the results of their operative removal. *New Engl. J. Med.*, 1941, *224:* 307–314.
6. Oldberg, E. Hemorrhage into gliomas. A review of eight hundred and thirty-two consecutive verified cases of glioma. *Arch. Neurol. Psychiat., Chicago*, 1933, *30:* 1061–1073.
7. Van Wagenen, W. P. Verified brain tumors. End results of one hundred and forty-nine cases eight years after operation. *J. Amer. med. Ass.*, 1934, *102:* 1454–1458.

# TUMOR OF THE GLOMUS JUGULARE WITH EXTENSION INTO THE MIDDLE EAR

## (NONCHROMAFFIN PARAGANGLIOMA OR CAROTID-BODY-TYPE TUMOR)*

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PRIMARY tumors of the middle ear and petrous portion of the temporal bone occur rarely and are usually observed by the otologist. Occasionally an invading tumor in this region will cause sufficient neurological disorder to bring the case to the attention of a neurologist or neurosurgeon. One of the authors encountered such a case with neurological signs and symptoms of primary importance, in which a carotid angiogram was helpful in delineating the tumor and determining future therapy.

### HISTORICAL REVIEW

In 1840 Valentine[11] originally described a slight swelling of the tympanic nerve; Krause later studied this structure more completely (1878) and noted its resemblance to the carotid body at the bifurcation of the common carotid artery.

Apparently this problem received little attention until 1941, when Guild[5] examined serial sections of human temporal bone and found small bodies (0.45–0.25 mm.) in the adventitia of the dome of the jugular bulb. Some of these bodies were situated along the tympanic branch of the glossopharyngeal nerve and others were below the tympanic cavity. They varied in size and position, and frequently two or more were found on each side. Histologically, these bodies resembled the carotid bodies at the bifurcations of the common carotid arteries. Guild believed the blood supply of these tumors was derived from the external carotid artery, through the tympanic branch of the ascending pharyngeal artery; he described the nerve supply arising from the glossopharyngeal nerve, through the *ramus tympanicum*. The location of these small bodies and their histological structure were confirmed by more recent work of Lattes and Waltner.[8]

In 1945 Rosenwasser[13] performed subtotal removal of a tumor in the middle ear, and Dr. Otani, who studied the histologic preparations, was impressed by the structural resemblance of this tumor to the normal carotid body. It was postulated that the tumor arose from the glomus jugulare, as described by Guild,[5] and this was the first time a tumor of this type was reported. Subsequently similar tumors were described by LeCompte, Som-

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mers and Lathrop[9] and Kipkie.[6] Winship, Klopp and Jenkins[14] reported 9 additional cases and reviewed histologic material from several cases which were reported previously. It would seem that several tumors in and about the middle ear and petrous portion of the temporal bone had been classified as endotheliomas and hemangioendotheliomas, although they were probably unrecognized tumors of the glomus jugulare. They found at least 11 such cases and 13 others which they suspected were probably tumors of the glomus jugulare, but exact identification was not possible.

Lundgren[11] reported 4 similar cases in which the lesions were termed "tympanic body tumors of the middle ear of the carotid body type," and the microscopic features of these tumors were elucidated, also, by Berg.[2] More recently De Lisa,[3] Dockerty, Love and Patton,[4] Poppen and Riemenschneider,[12] and Lewis and Grant[10] have reported additional cases in which tumors of the glomus jugulare were encountered.

In addition to confirming the presence of nests of cells resembling the carotid body in the region of the jugular bulb and middle ear, Lattes[7], and Lattes and Waltner[8] point out that similar structures are found also (1) in the ganglion nodosum of the vagus nerve, (2) in the adventitial portions of the ascending aorta, aortic arch, innominate artery and probably the pulmonary artery and (3) possibly in the orbit near the ciliary ganglion. They suggested that these structures be considered as homologous parts of a system composed of nests of nonchromaffin cells, of "epithelioid" type, situated in a perivascular stroma and resembling the carotid body histologically. Generally these structures are innervated by afferent fibers from a cranial nerve, and these authors believe the cell-nests probably function as chemoreceptors. However, these structures probably do not secrete epinephrine or other known hormones. The name "paraganglion" was suggested because this term had been used to designate the carotid body, which these structures resemble so closely. The term "nonchromaffin" was applied to differentiate such structures from the chromaffin paraganglion located in the adrenal medulla and the nests of chromaffin cells associated with the visceral sympathetic ganglia. Inasmuch as Lattes[7] reported tumors of this type in the ganglion nodosum and adventitia of the aortic arch, as well as in the region of the carotid body and glomus jugulare, the authors postulated that such tumors probably arise from nests of "epithelioid" cells normally situated in these locations.

Lattes and Waltner[8] studied their own histologic preparations and found a total of 8 cases that they classified as tumors of the glomus jugulare. Some of these had been classified in other categories prior to the above concept of derivation. Judging from their paper and the review of Winship, Klopp and Jenkins,[14] approximately 28 proved cases of tumors of the glomus jugulare have been reported in the literature, 22 of them in females.

To date only two reports concern instances in which patients with tumors of the glomus jugulare required neurosurgical exploration.[4,12] Angiography was used in studying the location and extent of the tumor in the case of

Poppen and Riemenschneider.[12] They reported a vertebral angiogram showed slight pooling of the thorotrast in the region of the tumor.

## CASE REPORT

A 35-year-old negro woman was admitted to the Kate Bitting Reynolds Memorial Hospital in Winston-Salem, June 24, 1950. Her chief complaint was that of hiccoughs for 1 month.

She had not been in good health for approximately 3 years and complained initially only of generalized weakness, for which she had been given thyroid extract without much benefit. One year prior to admission, she first noted deafness in her left ear and tinnitus associated with some ataxia. She had had some headache previously, but began to have headaches of greater severity. She denied having had any drainage in either ear or any bleeding at any time.

Four months before admission, she noticed one morning a sudden onset of paralysis of the left side of her face associated with numbness of the left face as

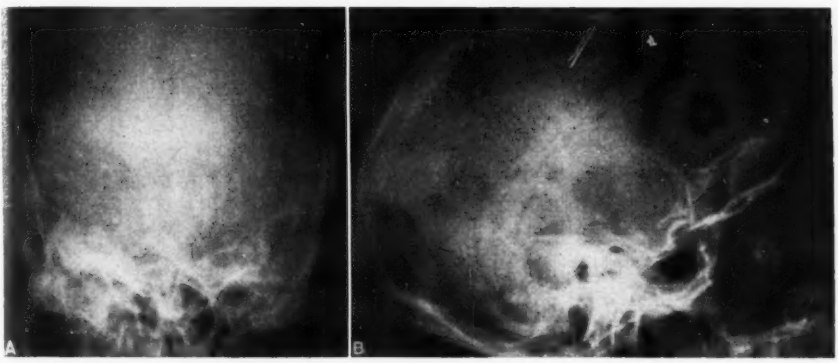

FIG. 1. Roentgenograms of skull. (A) A-P occipital view showing erosion of petrous portion of left temporal bone. (B) Right lateral view. Compare these plain films with the angiograms in Fig. 3.

well as the left side of her palate and tongue. There was increased ataxia and she felt that her voice took on a different tone. There was possibly slight numbness of the entire left side of her body but during the 3 months before admission, this had disappeared as well as the numbness of her face, tongue and palate.

One month before admission, hiccoughs began and were almost constantly present. She had been admitted to another hospital where a spinal puncture had been done; the CSF pressure and protein were reported as normal.

*Examination.* Temperature 98°, pulse 80, respirations 16 and B.P. 110/80. The patient was thin but fairly well developed. She hiccoughed during the entire examination. There was a "nasal twang" to her voice. Except for loss in weight, the general physical findings were normal, and there was no evidence of lymphadenopathy. When she was sound asleep, secretions collected in the posterior pharynx and were removed with some difficulty by the patient.

Palpation of the head revealed no abnormality. On auscultation, behind the left ear, a continuous murmur with a loud systolic component and a very faint diastolic component was heard. The first 6 cranial nerves showed no abnormalities. There

was no papilledema and no residual paralysis of the 5th cranial nerve, either motor or sensory. There was no nystagmus.

There was almost complete peripheral paralysis of the left 7th nerve with only faint motion of the orbicular oris on the left. There was complete paralysis of the 8th, 9th, 10th, 11th and 12th cranial nerves on the left. The vocal cords were not examined. The right ear drum was normal. The left ear drum showed, protruding through it, a smooth, red mass with very slight pulsations synchronous with the heart beat.

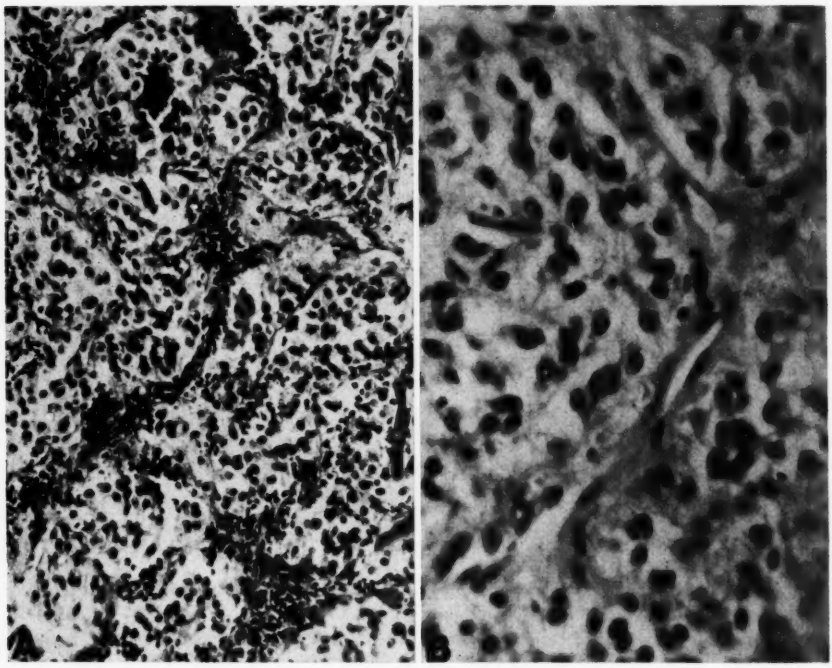

FIG. 2. Photomicrographs of tumor of glomus jugulare. (A) Low power (85×). (B) High power (145×). See text for detailed description.

There was ataxia of the left arm and leg. There were hyperactive deep tendon reflexes on the left, an unsustained ankle clonus of the left foot and a questionably positive Babinski response on the left.

*Laboratory Data.* RBC, WBC and Hb. were normal. Urine was normal. Blood Kahn was negative.

Roentgenograms of the chest were normal. The skull showed extensive destruction of the petrous portion of the left temporal bone with cloudiness of the left mastoid (Fig. 1).

*Biopsy* of the tumor mass in the left external auditory meatus was made by Dr. George Bradford. There was extensive bleeding from this which was controlled by packing the external meatus.

*Histological Study.* This is a relatively cellular tumor in which the cells are closely packed in an alveolus-like arrangement surrounded by fibrous-tissue stroma. The connective-tissue supportive stroma is generally variable in character, being dense in some areas while in others it is less prominent. The Masson's trichrome stain confirms the presence of an abundance of fibrous connective-tissue stroma between the alveolus-like arrangements of the cells. Within the stroma there are many large thin-walled vessels. The cells making up the alveolus-like structures are all equal in size, shape and staining property, and are uniformly hyperchromatic. Although the cells have a distinct basophilic nucleus, the cell borders are not well defined. The cytoplasm is palely eosinophilic and contains a few fine granules. No mitotic figures are seen (Fig. 2).

*Course.* Subsequently left common carotid angiography was performed by the open technique, using 35 per cent diodrast. The films (Fig. 3) show a normal vascular pattern for the anterior and middle cerebral vessels. In addition they disclosed a very vascular mass which filled the floor of the posterior fossa on the left side, ex-

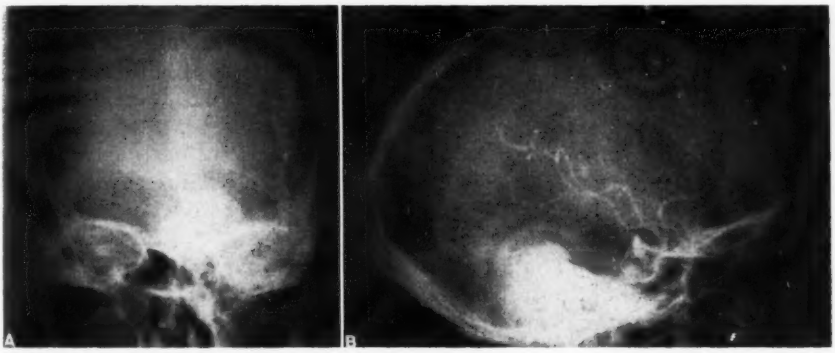

FIG. 3. Roentgenograms of skull after injection of 35 per cent diodrast into left common carotid artery. (A) A-P occipital view showing large vascular tumor in region of left temporal bone extending across the midline. (B) Right lateral projection. The vascular tumor extends from the middle fossa to the foramen magnum. The anterior and middle cerebral arteries appear normal.

tending slightly across the midline. It extended posteriorly as far as the foramen magnum and seemed to extend into the middle fossa as well. It was obvious that the petrous portion of the temporal bone was grossly involved by this very vascular tumor.

The left vertebral artery was also injected under direct vision with 35 per cent diodrast but no dye was evident in any of the films. Why the vessels associated with the basilar artery and the posterior cerebral artery failed to fill is not apparent. Possibly there was improper timing in exposure to the films.

Because of the extreme vascularity of this tumor and its very extensive nature with invasion of bone and obvious growth across the midline, it was felt that this tumor was not operable. The patient was, therefore, subjected to radiation therapy, receiving 2080 roentgen units (in air) through each of two 10×10 cm. occipital portals crossfiring to the tumor. The total dosage was administered over a 19-day period. About 6 weeks later she received further roentgen therapy in another city. On this occasion approximately 900 roentgen units were given through the left occipital portal, and 1200 R. through the right occipital portal. She noticed some

subjective improvement, particularly relief of hiccoughs, but there was no change in the objective findings. The tumor mass in the left ear remained approximately the same size, and the murmur over the left posterior fossa was still apparent when she was discharged. A letter from her family physician in April 1951 indicated the patient has shown definite improvement. She is now able to walk and to do her housework. Efforts to see the patient by the authors and to repeat the carotid angiogram have so far not been successful.

## DISCUSSION

Most tumors of the glomus jugulare now recorded in the literature were discovered because of signs and symptoms related to the ear; usually these were deafness and chronic otorrhea and, occasionally, complaints of dizziness, tinnitus and pain. Consequently, most of the cases were encountered by otologists and, in some instances, the tumors were small enough to permit complete or almost complete removal. In such cases, there was no apparent invasion of bone beyond the tympanic region, and it would appear that a cure could be expected. As mentioned before, certain tumors of this histological type occurred in more than one location; namely, the regions of the middle ear, the carotid body and the aortic arch. The tumor was regarded as malignant in only 3 cases. In the first, a case reported by Winship, Klopp and Jenkins [14] the tumor was regarded as malignant on the basis of histologic observations; there was extensive destruction of the left mastoid and petrous portion of the temporal bone and apparently there were metastases to regional lymph nodes in the neck. In the second instance (Case 3 of Lattes and Waltner[8]), autopsy studies revealed extensive invasion of the temporal bone with extension into the middle cerebral fossa. In addition to this, the liver contained a large focus which, although poorly preserved in the postmortem specimen, was regarded as tumor histologically similar to that in the petrous portion of the temporal bone. The third case, that of Poppen and Riemenschneider,[12] showed metastases to five local lymph nodes.

Tumors of the glomus jugulare are encountered most frequently in the age group from 30 to 50 years, but they have been found in patients as young as 23 and as old as 80 years. In the relatively small number of cases (28) thus far recorded in the literature, there is a higher incidence (22) in women. The medical history is usually of relatively long duration, and in at least 2 cases the patients suffered symptoms for 20 years or more.

There have been at least 7 deaths among the recorded cases of tumors of the glomus jugulare: 2 patients died following the attempted removal of the tumor; 4 died apparently of gross extension of the tumor into the intracranial cavity; and 1 died of meningitis and a cerebellar abscess. The outlook for our patient is obviously not good in view of the involvement of so many of the cranial nerves and the extension of the tumor to the middle and posterior cranial fossae. If roentgen therapy fails to give any substantial and permanent relief, and if the patient begins to show signs of increased intracranial pressure, it is possible that some relief of symptoms might be obtained by splitting of the tentorium, although this would be a very temporary measure.

Roentgen therapy has not been found to be particularly effective in tumors of this histologic type, occurring in the region of the carotid body, and it is likely, as has been indicated previously, this tumor will not be favorably affected by such treatment. Bevan and McCarthy[1] in 1929 reported striking diminution in the size of a carotid-body tumor 13 months after local roentgen therapy. A continued trial of roentgen therapy in tumors of this size invading the petrous portion of the temporal bone and with intracranial extension is indicated. Possibly Poppen's[12] suggestion of ligating the arterial supply to these tumors will be of benefit, although it is likely they receive some blood from both carotid and vertebral arteries when they attain large size. Guild's studies would point to the external carotid artery as the principal source of blood for the glomus jugulare.

It was found that the carotid angiogram was of valuable assistance in determining whether the particular tumor was operable, but it is well to point out that since there is great variation in the vascularity and some variation in the actual cellular structure of these tumors, all tumors of the glomus jugulare may not be demonstrated by carotid angiography so dramatically. In many patients coming to the neurologist or to the neurosurgeon because of involvement of the intracranial cavity, carotid angiography would appear to be a very valuable part of the neurological study.

## SUMMARY

1. A tumor of the glomus jugulare has been reported. Approximately 28 proved cases have been previously reported under the terms "glomus jugulare tumors," "tympanic body tumors" and "nonchromaffin paraganglioma of the middle ear."

2. These tumors are histologically similar to the carotid body tumors and to the rare tumor occurring in the region of the aortic arch.

3. Tumors of this type are locally invasive but usually benign and very slow in their growth. Occasionally such tumors can be removed completely when discovered in the early stages.

4. The extent and vascularity of the tumor in this case was demonstrated by carotid angiography.

5. Because of the x-ray appearance of this tumor in the plain skull films and in the angiograms, it has been considered inoperable and is being subjected to extensive radiation therapy.

6. It remains to be seen whether roentgen therapy will be effective in shrinking tumors of this type.

## REFERENCES

1. Bevan, A. D., and McCarthy, E. R. Tumors of the carotid body. *Surg. Gynec. Obstet.*, 1929, *49:* 764–779.
2. Berg, N. O. Tumours arising from the tympanic gland (glomus jugularis) and their differential diagnosis. *Acta path. microbiol. scand.*, 1950, *27:* 194–221.
3. De Lisa, D. A. Tumor of the glomus jugularis. *Arch. Otolaryng., Chicago*, 1950, *51:* 925–927.
4. Dockerty, M. B., Love, J. G., and Patton, M. M. Nonchromaffin paraganglioma of the middle ear; report of a case in which the clinical aspects were those of a brain tumor. *Proc. Mayo Clin.*, 1951, *26:* 25–32.

5. Guild, S. R. A hitherto unrecognized structure, the Glomus Jugularis, in man. *Anat. Rec.*, 194?, *79:* 28.
6. Kipkie, G. F. Simultaneous chromaffin tumors of the carotid body and the glomus jugulare. *Arch. Path.*, 1947, *44:* 113–118.
7. Lattes, R. Nonchromaffin paraganglioma of ganglion nodosum, carotid body, and aortic-arch bodies. *Cancer*, 1950, *3:* 667–694.
8. Lattes, R., and Waltner, J. G. Nonchromaffin paraganglioma of the middle ear (carotid-body-like tumor; glomus-jugulare tumor). *Cancer*, 1949, *2:* 447–468.
9. LeCompte, P. M., Sommers, S. C., and Lathrop, F. D. Tumor of carotid body type arising in the middle ear. *Arch. Path.*, 1947, *44:* 78–81.
10. Lewis, J. S., and Grant, R. N. Nonchromaffin paraganglioma of the middle ear (glomus jugulare tumor). *Arch. Otolaryng., Chicago*, 1951, *53:* 406–410.
11. Lundgren, N. Tympanic body tumours in the middle ear. Tumours of carotid body type. *Acta oto-laryng., Stockh.*, 1949, *37:* 367–379.
12. Poppen, J. L., and Riemenschneider, P. A. Tumor of carotid body type presumably arising from the glomus jugularis. *Arch. Otolaryng., Chicago*, 1951, *53:* 453–459.
13. Rosenwasser, H. Carotid body tumor of the middle ear and mastoid. *Arch. Otolaryng., Chicago*, 1945, *41:* 64–67.
14. Winship, T., Klopp, C. T., and Jenkins, W. H. Glomus-jugularis tumors. *Cancer*, 1948, *1:* 441–448.

## DISCUSSION

Dr. R. E. Semmes, Memphis, Tennessee: A housewife, aged 32, had had an intermittent blowing sound in the right ear, synchronous with the heart beat, for 3½ years, pain in the right ear for 1 year, and weakness in elevating the right shoulder for 1 year. A red discoloration across the right ear drum had been present for 1 year.

Because of these symptoms, a spinal fusion for spondylolisthesis was deferred. After several months the pain in the ear subsided, and fusion was carried out on Jan. 4, 1951.

Shortly thereafter, the pain returned, the blowing noise increased, and there developed weakness of the right side of the tongue, paralysis of the sternocleidomastoid muscle, and ringing and diminished hearing in the right ear. Compression of the jugular vein resulted in no changes but compression of the common carotid artery stopped the bruit and the pain—which returned promptly on release of the vessel.

Roentgenograms of the skull showed questionable enlargement of the jugular foramen.

An arteriogram of the right internal carotid was negative. The carotid was then exposed and it was found that compression of the internal carotid stopped the bruit and the pain, but compression of the external carotid, which was small, had no effect. An arteriogram of the vertebral was negative. Weakness of the 9th, 10th and 12th nerves was observed, pointing to the jugular foramen.

On Jan. 29, 1951, a right suboccipital exploration was done through a straight incision and a firm, tough, pinkish tumor, about 2 cm. in diameter, was found blocking the jugular foramen. It was moderately vascular and incorporated the 9th, 10th and 11th nerves. The 11th nerve could not be saved and damage was done to the 9th and 10th. The tumor was adherent to the 8th. It was removed completely as far as could be determined and the dural attachment of the foramen was lightly cauterized.

Postoperatively there was no pain in the ear, the bruit was gone, the 11th, 10th, and 9th nerves were out of commission, there was increased deafness, and 3 days later paralysis of the 7th, which later cleared.

Dr. Exum Walker, Atlanta, Georgia: A 32-year-old male complained of pounding noise in the right ear of 5 years' duration. There was slight deafness in the right

ear and a definite tenseness and bluish discoloration of the right ear drum. Carotid compression stopped the pounding noise.

On June 22, 1950, right arteriography was done. No abnormality was seen in any of these films. Ordinary x-rays of the skull showed clouding of the right mastoid region, interpreted as thickening of the mucosa.

In January 1951, a right facial paralysis developed. The patient was operated upon by an otologist, Dr. Leslie Brown, who found a tumor filling the region of the middle ear and pressing the carotid artery in the carotid canal. The tumor was said to have been completely removed but the facial nerve could not be spared. Histological diagnosis was nonchromaffin paraganglioma.

Dr. Brown stated that he had removed 1 other such tumor and had seen 3 additional cases of this type.

Dr. Jess D. Herrmann, Oklahoma City, Oklahoma: A 59-year-old housewife complained of excruciating pain in the left side of her face over the trigeminal area. Some 20 years before, a "blood tumor" had been removed from the left external canal, and about that time she noted loss of hearing on the left. About 7 years later paroxysmal attacks of pain developed in the left cheek. Two years before we saw her, she had had an alcohol injection of the infraorbital nerve which had relieved the sharp, stabbing pain but the "drawing pain" persisted. A year and a half before, a mass was seen in her external auditory canal and a biopsy was attempted, but bleeding was so profuse that no tissue was obtained.

There was involvement of the 5th nerve on the left with hypesthesia of the 1st and 2nd divisions. The motor root was not involved but there was corneal hypesthesia. There was a peripheral 7th nerve weakness which, from the history, had been present for some 5 years. There was total deafness with a dead labyrinth and there was also left 9th and 10th paralysis. Roentgenograms of the skull showed erosion of the left petrous bone.

At operation through the temporal route, a tumor mass was found extending through the anterior portion of the petrous bone. It had eroded the dura. It was quite vascular and we felt that it must be some kind of carcinoma. Our pathologist informed us of the true nature of this tumor. It was a tumor of the glomus jugulare.

# CASE REPORTS AND TECHNICAL NOTES

## OBSERVATIONS ON PHANTOM LIMB IN A PARAPLEGIC PATIENT

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The history of "phantom limb" has been, perhaps, as long as the history of the human race. But this phenomenon did not receive attention until 1871 and 1872, when Mitchell[20,21] first introduced this terminology and reported his series of 90 cases. Mitchell's description was vivid; and since his time, numerous reports of the "misbehavior ghost" have appeared in the literature. Most workers believe that the phantom impression has an organic basis,[10,11,14,16,17,18,25,27] while others claim that it is psychogenic.[1,22,24] Treatment has included: various types of procedure directed to the stump and to the central end of the divided nerves,[2,21] interruption of the sympathetic pathways,[14,17,30] posterior rhizotomy,[7] combined posterior and anterior root sections,[7] combined sympathectomy and posterior rhizotomy,[7] combined sympathectomy with anterior and posterior rhizotomy,[4] anterolateral chordotomy,[6,8] dorsal chordotomy,[3] post-central gyrectomy,[5,10,12] bilateral frontal lobotomy,[29] electric shock treatment,[23] and hypnosis and psychotherapy.[9]

Because of the obscurity that still surrounds the problem of phantom limb it was felt that the present rather unusual case should be reported. The patient had suffered a fracture of the 7th and 8th thoracic vertebrae with complete paraplegia below the nerve segments D6 and D7. At the same time he had sustained an injury to his leg which required amputation 8 days after the accident. Four days after the amputation phantom limb with causalgia developed in spite of the complete physiological interruption of impulses at the level D6 and D7. Below are recorded various procedures employed in an attempt to alleviate the symptoms and to study the mechanism of transmission of the impulses involved.

### REPORT OF CASE

G.R. was a volunteer fireman, aged 36. On Jan. 10, 1949 he was called to fight a fire, and, while handling the hose, was struck on the back by a collapsing chimney. He was immediately rendered unconscious and, on awakening, he was not aware of sensation below his chest. He was taken to a local hospital, where a diagnosis of spinal injury was made. A compound fracture of the left leg and a simple fracture of the right 6th rib were also found. The wound was debrided and sutured, and finally the leg was placed in a skin-tight plaster cast. Arrangements were made to fly the patient to Montreal for further treatment. He arrived on a body-length board 24 hours after the accident.

*Examination.* There was complete paraplegia with loss of sensory and motor function below and including the level of dermatome D6 on the right and D7 on the left. Limitation of respiratory excursion of the right chest was observed and exquisite tenderness over the right 6th rib posteriorly was elicited. The left lower limb was in a cast; the exposed foot and toes were swollen and cold.

A cystometrogram disclosed an atonic bladder. The lumbar manometric test showed a

complete block. The CSF was slightly straw-colored; it contained 129 RBC/c.mm. and 160 mg. per cent of protein.

X-rays of the spine revealed a compression fracture of the body of the 8th thoracic vertebra, and a fracturing of the 7th laminal arch. X-rays also demonstrated a fracture of the right 6th rib, and a comminuted fracture of the mid-third of the left tibia and fibula.

On removal of the cast a lacerated wound, measuring 20 cm. in length, was found over the medial aspect of the leg. The leg as a whole was swollen and cold, especially the foot and toes. Pulsation of the dorsalis pedis and the popliteal artery was faintly perceptible. A new plaster was applied.

*Course.* On January 16, the patient appeared toxic and required blood transfusion. His temperature had remained persistently high despite antibiotic therapy. Pulsation of the dorsalis pedis artery could not be felt. The wound became more edematous and the surrounding skin cyanotic. A considerable amount of necrotic tissue was excised and the wound was re-packed. Cultures showed moderate growth of enterococci on aerobic and anaerobic media.

On January 17, further debridement was carried out. Palpation still failed to reveal pulsation in the dorsalis pedis artery. His temperature was 103°F. Pulse and respirations were rapid.

On January 18, 8 days after the accident, disarticulation was performed at the knee. His general condition rapidly improved and his temperature gradually returned to normal.

*Development of Phantom Limb.* Four days after the amputation the patient began to be aware of his absent left limb in spite of the existing paraplegia below the level of D6 and D7. He felt that his left leg was extended and the ankle slightly flexed. The phantom foot felt as if it were tightly bandaged and the toes crowded. He was not able to move the phantom. There was a sensation of "pressure pain" in the phantom limb, especially over the dorsum of the foot and the shin.

A sweating test one month after the amputation showed an absence of perspiration below the 2nd lumbar dermatome bilaterally, while slight perspiration was observed over the 1st lumbar and 12th thoracic, and marked perspiration above the 10th thoracic dermatome.

### *Investigative Procedures*

On March 21, unilateral left lumbar paravertebral sympathetic block was carried out. The skin temperature and the skin resistance were recorded at various corresponding points on both lower extremities before and after the injection. After the injection, the skin of the stump showed an increase of temperature and resistance which suggested that the sympathetic pathways were not completely interrupted as a result of the accident. The patient continued to have the phantom impression and pain in spite of the lumbar sympathetic block.

On April 5, with great effort the patient thought that he had "shaken off" the sensation as of a tight bandage in the phantom foot, and that his toes were movable and that the sole of the foot was resting on a soft pillow. On the same day a left lumbar paravertebral block was repeated, but again no change of the phantom was obtained. Immediately thereafter injection of 4 cc. of 2 per cent novocaine was made into the subarachnoid space at a level between the 3rd and 4th lumbar vertebrae. As there was no sensation below the level of D7, these procedures were accomplished without pain. The sensory level was not raised by the spinal anesthetic.

After the above spinal subarachnoid injection the patient reported that his phantom limb and pain had disappeared. Twenty-five minutes after the injection the phantom returned, but its existence was vague and he was not sure which part of his limb was present. One and a half hours after the injection the patient was conscious of the presence of his knee and the great toe. He could not wiggle the solitary toe but there was no more pain.

On April 10, the patient reported that the whole length of the phantom member had returned. In addition he became aware of his right lower paralyzed extremity. He thought that both were extended but the left foot was caught under the heel of the right foot, giving

rise to "pressure pain" in the dorsum of the left foot. He felt no movement except in the left toes.

Later in the day a bilateral lumbar paravertebral sympathetic block and lumbar spinal anesthesia were performed (for the latter 25 cc. of 1/1500 nupercaine were used which practically replaced the residual CSF below the block). The sensory level was not raised by the spinal anesthetic. These procedures failed to alter the phantom pattern and painful sensation. Further interruption of the sympathetic pathways was added by blocking the upper thoracic sympathetic chains and the stellate ganglia on both sides. No effect on the phantom was obtained.

At a later date 0.3 cc. of 6 per cent sodium chloride solution was injected into the ligaments of the spine at three different levels just above and at all the levels below the site of injury.[11] This was based upon the theory that the provoked impulses reaching the sensorium of the spinal cord diffuse in the grey matter, thus disturbing painful sensations reaching the same region of the cord via pain tracts from more superficial tissues.[15,19,26,28] In this case the phantom pattern and the phantom painful sensation might have been disturbed. However, our experiment did not support this hypothesis. The injection of the hypertonic saline into the spinous ligaments did not change the phantom impression.

Faradic stimulation of the stump of the disarticulated limb did not produce any response. Stimulation of the sciatic nerve caused violent backward contraction, slight internal rotation and adduction of the thigh, which were not felt by the patient, nor was there any change of his phantom sensation. EEG tracings demonstrated a well regulated low-voltage alpha activity on both sides. Attempts to produce "evoked" potentials with the use of tactile, pin-prick and faradic stimulation of the amputated stump and its severed nerves were made simultaneously with recordings from the right central and postcentral regions. There were no genuinely evoked potentials recorded and only movement artifact resulted, probably from the startle reaction on the part of the patient.

Exploratory laminectomy at D7, D8 and D9 was performed on April 21, 1949. The laminal arch of D7 on the left side was found fractured. The fragments were not displaced. The epidural connective tissue was adherent to the dura. On opening the dura there were very thick and rather extensive adhesions, about 1 cm. wide, underneath the upper portion of D8. These constricted the cord to about two-thirds of its normal diameter. The lower segment of the cord was whitish and appeared avascular. The normal anatomical markings were lost. The cord below the constriction was swollen and increased by about one-third of its normal size. Aspiration at the site of maximal swelling did not yield fluid.

In parallel with his recovery from the general anesthesia of the operation the left phantom limb returned. It retained its former position and was composed of a stump and a foot. The ankle of the foot was immobile but the patient could wiggle his toes. "Pressure pain" was experienced over the dorsum of the phantom left foot which was caught under the right heel. The existence of the right lower extremity was, however, vague and was present only when the concentration of the patient was directed to it. The right lower limb was never painful.

The patient stayed in the hospital until his urinary bladder became automatic. His reaction to his prolonged hospitalization would seem to indicate that he was a well-balanced individual. He was discharged to the Paraplegic Centre for rehabilitation on May 27, 1949.

## SUMMARY

1. A case is reported in which disarticulation of the left leg at the knee was performed 8 days after the patient had been rendered paraplegic by a spinal injury. Phantom limb developed 4 days after the amputation.

2. Attempts to detect the pathways of the afferent impulses from the phantom limb and to change its character included: 1) left lumbar sympathetic block; 2) spinal anesthesia with novocaine; 3) complete sympathetic block (bilateral lumbar and bilateral stellate ganglion) plus replacement of the subarachnoid fluid with

nupercaine below the site of the injury; 4) injection of hypertonic saline into the interspinous ligaments above and below the level of the lesion; 5) peripheral faradic stimulation and electroencephalographic recording; 6) spinal exploration under general anesthesia.

3. Except for the first spinal subarachnoid novocaine anesthesia following a left lumbar paravertebral sympathetic block, none of the above procedures gave any relief.

## REFERENCES


1. Bailey, A. A., and Moersch, F. P. Phantom limb. *Canad. med. Ass. J.*, 1941, *45:* 37–42.
2. Boldrey, E. Amputation neuroma in nerves implanted in bone. *Ann. Surg.*, 1943, *118:* 1052–1057.
3. Browder, J., and Gallagher, J. P. Surgical treatment of painful phantom limb. A preliminary report. *N. Y. St. J. Med.*, 1946, *46:* 2403–2405.
4. Cone, W. V. Personal communication.
5. Echols, D. H., and Colclough, J. A. Abolition of painful phantom foot by resection of the sensory cortex. *J. Amer. med. Ass.*, 1947, *134:* 1476–1477.
6. Falconer, M. A., and Lindsay, J. S. B. Painful phantom limb treated by high cervical chordotomy. Report of two cases. *Brit. J. Surg.*, 1946, *33:* 301–306.
7. Foerster, O. Der Schmerz und seine operative Bekämpfung. *Nova Acta Leop. Carol.*, 1935, n.s. *3:* 1–60.
8. Foerster, O., and Gagel, O. Die vorderseitenstrangdurchschneidung beim Menschen. Eine klinisch-patho-physiologisch-anatomische Studie. *Z. ges. Neurol. Psychiat.*, 1932, *138:* 1–92.
9. Guillaume, J., Froideveaux, and Mazars. Traitement des membres fantômes douloureux par psychothérapie sous narcose ou hypnose. *Rev. neurol.*, 1947, *79:* 213–215.
10. de Gutiérrez-Mahoney, C. G. The treatment of painful phantom limb by removal of postcentral cortex. *J. Neurosurg.*, 1944, *1:* 156–162.
11. Head, H., and Holmes, G. Sensory disturbances from cerebral lesions. *Brain*, 1911, *34:* 102–254.
12. Horrax, G. Experiences with cortical excisions for the relief of intractable pain in the extremities. *Surgery*, 1946, *20:* 593–602.
13. Kellgren, J. H. Somatic simulating visceral pain. *Clin. Sci.*, 1940, *4:* 303–309.
14. Leriche, R. Les douleurs des moignons d'amputation. *Pr. méd.*, 1932, *40:* 869–873.
15. Lewis, T. Pain. *New York: Macmillan Co.*, 1942, xiii, 192 pp.
16. Livingston, K. E. The phantom limb syndrome. A discussion of the role of major peripheral nerve neuromas. *J. Neurosurg.*, 1945, *2:* 251–255.
17. Livingston, W. K. Fantom limb pain. A report of ten cases in which it was treated by injections of procaine hydrochloride near the thoracic sympathetic ganglions. *Arch. Surg., Chicago*, 1938, *37:* 353–370.
18. Livingston, W. K. Pain mechanisms. A physiologic interpretation of causalgia and its related states. *New York: Macmillan Co.*, 1943, xiv, 253 pp.
19. Mackenzie, J. Symptoms and their interpretation. *London: Shaw & Sons*, 1909, xx, 297 pp.
20. Mitchell, S. W. Phantom limbs. *Lippincott's Mag. pop. Lit. Sci.*, 1871, *8:* 563–569.
21. Mitchell, S. W. Injuries of nerves and their consequences. *Philadelphia: J. B. Lippincott & Co.*, 1872, 377 pp.
22. Pick, A. Zur Pathologie des Bewusstseins vom eigenen Körper. Ein Beitrag aus der Kriegsmedizin. *Neurol. Zbl.*, 1915, *34:* 257–265.
23. Pisetsky, J. E. Disappearance of painful phantom limbs after electric shock treatment. *Amer. J. Psychiat.*, 1946, *102:* 599–601.
24. Randall, G. C., Ewalt, J. R., and Blair, H. Psychiatric reaction to amputation. *J. Amer. med. Ass.*, 1945, *128:* 645–652.
25. Riddoch, G. Phantom limbs and body shape. *Brain*, 1941, *64:* 197–222.
26. Ross, J. On the segmental distribution of sensory disorders. *Brain*, 1888, *10:* 333–361.
27. Souques, and Poisot. Origine périphérique des hallucinations des membres amputés. *Rev. neurol.*, 1905, *13:* 1112–1116.
28. Sturge, W. A. The phenomena of angina pectoris, and their bearing upon the theory of counter-irritation. *Brain*, 1883, *5:* 492–510.
29. van Wagenen, W. P. Cited by White.[30]
30. White, J. C. Pain after amputation and its treatment. *J. Amer. med. Ass.*, 1944, *124:* 1030–1035.

# ANOMALOUS INNERVATION OF THE HAND MUSCLES

## CASE REPORT

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The pattern of ulnar and median nerve innervation for the intrinsic hand muscles commonly deviates from classical description.[1,2] During the routine examination of approximately 500 consecutive nerve injuries seen at Walter Reed Army Hospital, variations in the innervation of the flexor carpi ulnaris, flexor pollicis brevis, the lumbricales and the interossei have been recognized frequently. One case has been outstanding in this respect. All of the intrinsic hand muscles received innervation, in part at least, from the median nerve.

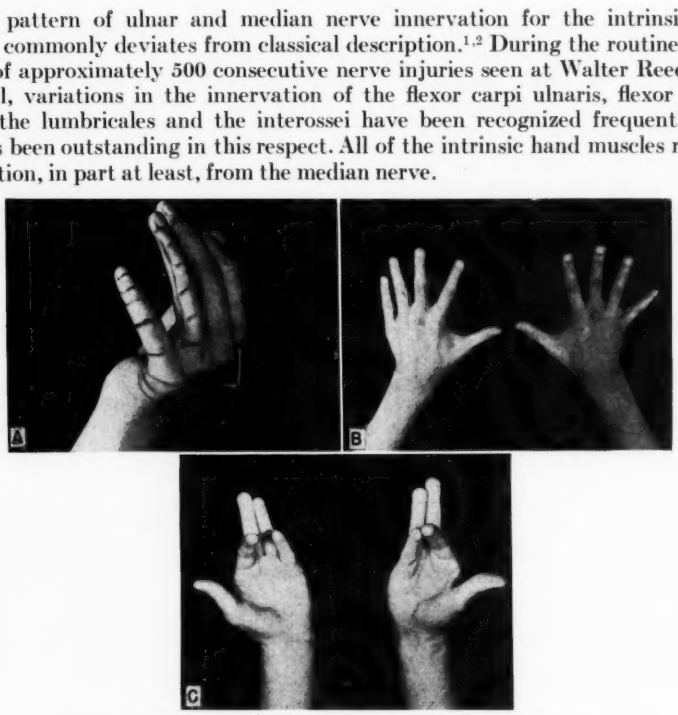


FIG. 1. Representing the degree of deficit present on 31 July 1950.

## CASE SUMMARY

A 17-year-old white male was shot at close range just above the left elbow on 12 November 1949. The wound was initially debrided, cleansed, and closed, and tetanus toxoid administered. His ulnar sensory deficit was noted 3 days later. He was transferred to this neurosurgical center 1 month after injury. On that admission he had a healed, irregular, stellate, tender scar on the medial side of the arm above the elbow. The sensory deficit indicated an ulnar nerve lesion, but significant muscle weakness was limited to the flexor carpi ulnaris†

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† Ten per cent palpable muscle contraction without joint movement; 20 per cent complete range of motion with gravity eliminated; 50 per cent complete range of motion against gravity; 70 per cent complete range of motion against gravity with some resistance.

(35 per cent), the abductor digiti quinti (10 per cent), the opponens digiti quinti (10 per cent), and the 4th dorsal (35 per cent), and 3rd palmar interossei (20 per cent). Sensory deficit was limited to the ring and little fingers (Fig. 1, A).

Six months after admission the sensory pattern was unchanged. Percussion of a small neuroma under the scar caused severe pain in the ring and little fingers. All intrinsic muscles of the hand were stronger than 70 per cent, except the abductor and adductor digiti quinti which had increased in strength to 50 per cent (Fig. 1, B and C). In August 1950 a scarplasty was done and the ulnar nerve explored. The nerve ends lay about 1½ inches apart and were bound in dense adhesions beneath the scar. Neither response in the intrinsic hand muscles, nor sensation in the little finger was demonstrable on stimulation of the distal segment. An anterior transplant and neurorrhaphy were performed (by Gordon T. Wannamaker, Captain, M.C.). No aberrant branch from the median to the ulnar nerve could be found within 6 inches below the elbow. There was no change in the sensory pattern or strength of the hand muscles following this procedure. The postoperative course was uneventful. The strength in all the intrinsic hand muscles reached 70 per cent before he returned to full military duty in October 1950.

All the intrinsic hand muscles in this instance were evidently innervated through an unusual distribution of the median nerve. This anomaly illustrates an extreme instance of a commonly encountered variation which one must consider in diagnosis of lesions of the ulnar and median nerves.

## REFERENCES

1. Haymaker, W., and Woodhall, B. Peripheral nerve injuries. Principles of diagnosis. *Philadelphia: W. B. Saunders Co.*, 1945, xiv, 227 pp. (see pp. 154, 164).
2. Seddon, H. J. War injuries of peripheral nerves. *Brit. J. Surg., War Surgery suppl. 2*, 1949, 325–353 (see p. 331).

# NEUROLOGIC COMPLICATIONS ASSOCIATED WITH HEREDITARY DEFORMING CHONDRODYSPLASIA

## REVIEW OF THE LITERATURE AND A REPORT ON TWO CASES OCCURRING IN THE SAME FAMILY

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Hereditary deforming chondrodysplasia is described[16] as a congenital abnormality of osteochondral development, resulting in irregularity and arrest in growth at the metaphyseal ends of long bones, causing deformity and the occurrence of multiple cartilaginous masses which with calcification become osteo-cartilaginous.

Various names have been given to this condition. The most frequently used are: hereditary deforming chondrodysplasia,[10,15,18,22,37] multiple cartilaginous exostoses,[1,9,13,21,25,26,30] dyschondroplasia[6,23,27] and diaphysial aclasia.[20]

A difference of opinion exists as to the etiology of this disorder but the general consensus points to a disturbance of the process of proliferation and ossification in the intermediary cartilage period of skeletal growth.[6,9,20,37]

The first description of a case of multiple exostoses is credited to Key in Guy's Hospital Reports of 1825.[17] However, in the *Surgical Essays* by Astley Cooper and Benjamin Travers[8] in 1821, an account is given of the case of Mr. Abernethy "of

a boy who came out of Cornwall, who was so excessively afflicted with an apparent predisposition to exostosis, or an exuberant deposition of bone matter, that a very trifling blow would occasion a bony swelling in any bone of his body. His ligamentum nuchae was ossified, . . . so that he was as it were completely pinioned; besides all this, the subject in question had numerous other exostoses in various parts of the body."

*Familial Incidence.* The familial nature of the disease was first noted by Stanley[34] in 1849. Reinecke[30] in 1891 reported on 176 cases occurring in 36 families running through to the fifth generation. Gibney[13] in 1875 described the first case in the American literature and the familial incidence in 1876.[14] In 1917, Ehrenfried[10] reviewed over 300 articles and found about 600 cases of this condition. Leucutia and Price,[22] in 1929, found more than 700 cases but their review is rather incomplete because Stocks[35] had reported 765 cases in 1925. Reports of other cases of familial involvement have followed since then.[12,15,18,31,36,37] One of these[31] described four members of a negro family who were afflicted by this condition.

*Differential Diagnosis.* Hereditary deforming chondrodysplasia must be differentiated from:

(1) Achondroplasia (chondrodystrophia fetalis)[16]—a congenital dystrophy of the growth cartilage occurring in utero and characterized by dwarfism, deformities and a bull-dog facies.

(2) Morquio's Syndrome[11,32]—a disorder of epiphyseal development with frequent absence of heads of femora and deformity of the spine, with crippling and dwarfism.

(3) Maffucci's Syndrome[21]—a dyschondroplasia associated with multiple hemangiomata and roentgen manifestations of multiple small cystic areas, particularly of small bones.

(4) Ollier's Disease—a unilateral development of single or multiple exostoses. Some writers[4,16] believe that this disease is similar to hereditary deforming chondrodysplasia, especially since in Ollier's original case[27] there was actually bilateral involvement. However, others[19,24,33] consider this a separate entity because of its non-hereditary nature, generally unilateral distribution and roentgenographic signs of cystic changes similar to those of osteitis fibrosis cystica.

FIG. 1. *Case 1.* Asymmetry and deformities of the extremities produced by hereditary deforming chondrodysplasia.

(5) Single bony exostoses, which are of frequent occurrence and pathologically are generally osteomas.

*Neurologic Complications.* Approximately 1000 cases of hereditary deforming chondrodysplasia have been reported. In 1925 Stocks[35] reviewed 765 cases reported in all literature. In these and in cases reported subsequently in the English literature, neurologic complications were found to be rare. In many instances the reported complica-

tion was secondary to a single exostosis not necessarily of chondrodysplastic origin; in others the complication appeared to be the result of an associated neurologic disease and not secondary to an exostosis.

Neurologic complications have been reported by various authors.[1–3,5,7,10,12,26,28,29,34,35] We have reviewed the available case histories of patients reported as having neurologic complications and these appeared to fall into two groups. Group I consisted of cases in which, in our opinion, the findings did not support a diagnosis of hereditary deforming dyschondroplasia or in which the neurologic disturbance suggested an unrelated disease associated with the dyschondroplasia. There were 11 cases in this group. Group II consisted of 19 cases in which the neurologic complication was directly related to an encroaching osteochondral exostosis. For the sake of brevity we have given the reference numbers only to these reported cases.

FIG. 2. *Case 1.* Left femur and leg showing bone changes typical of hereditary deforming chondrodysplasia.

Because of the rarity of actual neurologic complications of so common a condition we are presenting 2 personally observed cases in which the etiology was proved and which occurred in the same family. In one case an exostosis of the cervical vertebrae compressed the spinal cord. The second patient, a brother of the first, had an exostosis of the femur compressing the sciatic nerve. Two children of the second patient also bear uncomplicated stigmata of the disease.

*Case 1.* File No. 210621. F.N., a 33-year-old unmarried white man, was admitted Oct. 8, 1949 to the Buffalo General Hospital on the Neurologic Service of Dr. Burton M. Shinners. He complained of paresthesias of the left 3rd and 4th fingers that had persisted since January 1949, followed by numbness of the hand, progressive weakness of the fingers and forearm, and impaired finger dexterity. In April 1949, he noticed a descending loss of sensation of the right lower extremity, urgency, frequency, dribbling of urine and suprapubic discomfort. Cough, sneeze and other forms of straining aggravated the pains and paresthesias.

*Examination.* He was a well developed man with obvious multiple skeletal deformities (Fig. 1). A large irregular mass was palpable in the left cervical area; a second mass was palpable in the left upper arm; smaller masses were found over the 5th and 6th ribs on the right; and a 10 cm. mass was in the left posterior tibial area. There was atrophy of the left supra- and infraspinatous, biceps and deltoid muscles. The circumference of the right upper extremity was greater by 1.0 to 4.5 cm. than the left, while the left mid-calf circumference was 44.5 cm. as compared to 37.5 cm. on the right. The left forearm was 3.5 cm. shorter than the right.

Positive neurologic findings were: a depressed left biceps reflex, hyperactive triceps and radial responses, and a left Hoffmann sign. The left lower deep tendon reflexes were more active than the right, with a Babinski sign and unsustained patellar clonus. Vibration sense was impaired on the left and position sense bilaterally. Hypalgesia was present over the left C6 dermatome distribution (deltoid area), the left forearm and proximal thumb areas (C5–6). Hypalgesia was present on the right side below D10 and decreasing hypalgesia from

D10 to C6. Touch sensation was preserved. The sensory changes on the right and pyramidal tract signs on the left suggested an incomplete Brown-Séquard syndrome at C5 cord level.

Roentgenograms on Oct. 8, 1949, showed multiple broad-based osteochondromas most evident on the left femur and leg (Fig. 2), and over C5 and C6 vertebrae (Fig. 3 A and B). Spinogram showed a complete subarachnoid block at C6 (Fig. 3 A).

*Operation.* At laminectomy at C5–C6 level, the vertebral canal was found narrowed in the anteroposterior diameter; the dura was elevated and displaced to the right by a grumous bony tumor. The intervertebral part of the tumor was removed but the paravertebral extension was too massive for removal at that time.

*Histologic Report.* A lobulated mass of hyaline cartilage with myxomatous degeneration in many areas (Fig. 4 A).

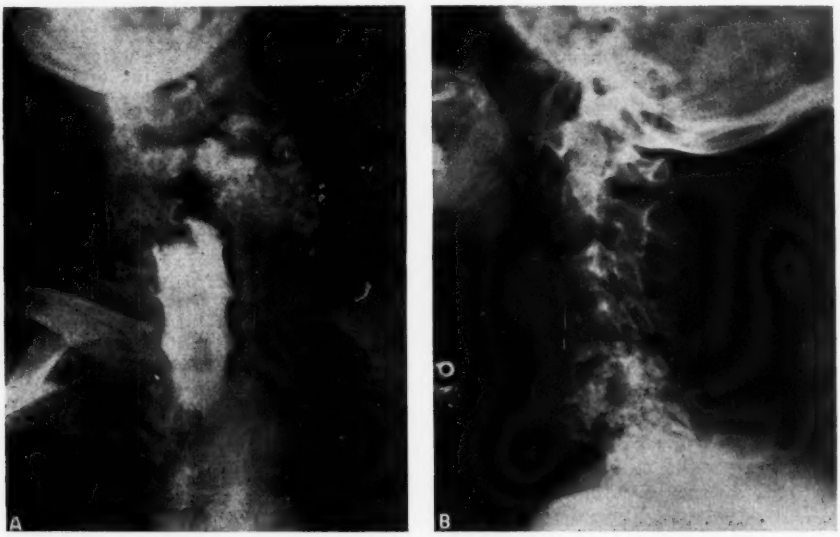


FIG. 3. *Case 1.* (A) Cervical myelogram showing complete block at C6 vertebra produced by extradural compression by a bony tumor mass. (B) Lateral view of cervical spine showing location and extent of the osteochondroma.

*Course.* After operation the patient improved subjectively but at discharge 12 days later the neurologic status was unchanged. He has not returned for examination but is known to be working daily as a stock clerk and is asymptomatic except for some shoulder pain.

*Case 2.* File No. 214985. A.N., a 37-year-old man, brother of Case 1, was admitted April 6, 1950, to the Buffalo General Hospital on the Neurologic Service of Dr. Burton M. Shinners. During the past 8 months he had suffered paresthesias and cramping of the left posterior thigh and recurrent attacks of radiating sciatic pain.

*Examination.* He was a well developed man of small stature who had a large palpable mass over the left femur. Roentgenograms showed diffuse widening of the lower femoral shaft and a large cauliflower-like osteochondroma of the upper femur (Fig. 5 A) in the region of the lesser trochanter. Forearms and legs (Fig. 5 B) showed similar widening of the upper and lower shafts with shortening of the forearms and multiple osteochondromas.

*Operation.* The nodular femoral osteochondromas were removed later by Dr. Benjamin Obletz of the Orthopedic Staff.

*Histologic Report.* Osteochondroma (Fig. 4 B) with a broad base, having a thick cap of hyaline cartilage and covered by a thick fibrous perichondrium. Many areas of mucoid degeneration were seen in the cartilage.

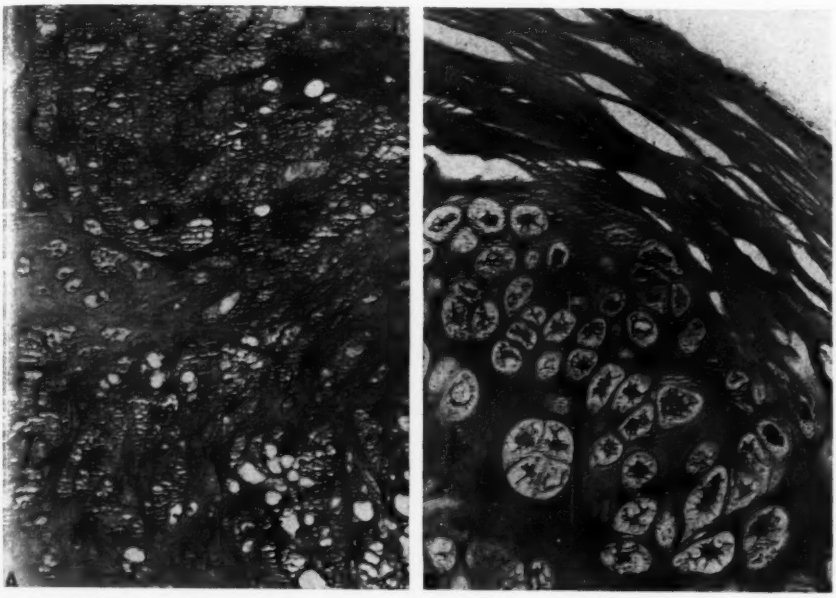

FIG. 4. (A) *Case 1.* Osteocartilaginous tissue with fairly uniform chondrocytes and areas of myxomatous degeneration. (B) *Case 2.* Thick fibrous capsule surrounding osteocartilaginous tissue with large uniform chondrocytes.

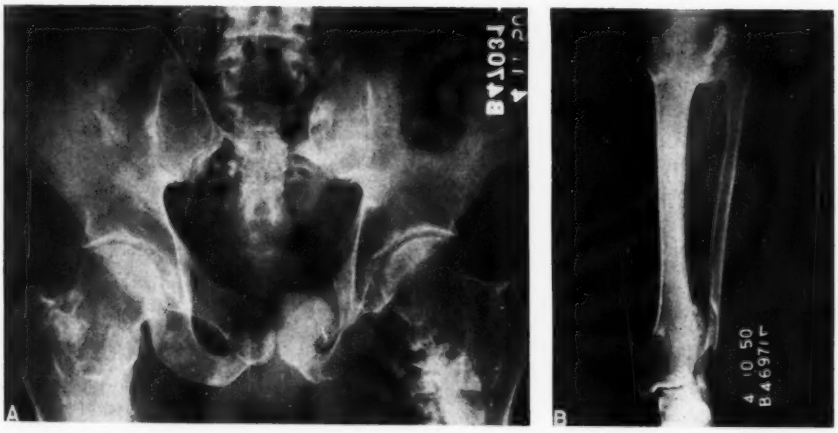

FIG. 5. *Case 2.* (A) Pelvis and femora with changes typical of hereditary deforming chondrodysplasia. The osteochondral tumor arising from the left upper femur produced the sciatic pain. (B) Changes in distal and proximal ends of left tibia and fibula, increased density of osteochondral growth at proximal tibiofibular articulation, and exostoses demonstrating the diffuse bony involvement.

FIG. 6. (A) Roentgenogram of both legs showing the broad bases and exostoses typical of hereditary deforming chondrodysplasia in 7-year-old son of Case 2. (B) The left forearm and both legs show similar changes in the 2½-year-old son of Case 2.

*Course.* The patient had complete relief of paresthesias and pain. The roentgenograms of his two sons, aged 2½ and 7 years, are presented in Fig. 6.

## SUMMARY

Nineteen cases of neurologic complications of chondrodysplasia have been found in the literature. Two new cases occurring in brothers are described, making a total of 21. Two children of one of our patients manifest asymptomatic stigmata of chondrodysplasia. The male sex was involved in 14 of 15 reported cases where the sex is mentioned. The spinal cord was involved in 10 cases, the sciatic nerve in 6, the peroneal nerve in 2 and the brachial plexus and ulnar nerve in 1 case each. One case was reported without specific nerve involvement. A brief review of the literature is presented.

## REFERENCES

1. ASHHURST, A. P. C. Multiple cartilaginous exostoses (hereditary deforming chondrodysplasia) with notes of nine hitherto unpublished cases. *Ann. Surg.*, 1916, *63:* 167–175.
2. BENTZON, P. G. K. Roentgenological and experimental studies on the pathogenesis of the dyschondroplasia (Ollier's disease). *Acta radiol., Stockh.*, 1924, *3:* 89–112.
3. BOGGS, T. R. Multiple congenital osteochondromata with degeneration of cranial nerves and muscular dystrophy. Report of case. *Johns Hopk. Hosp. Bull.*, 1913, *24:* 210–211.
4. BROMER, R. S., and JOHN, R. L. Ollier's disease, unilateral chondrodysplasia. Report of a case with a review of the literature. *Amer. J. Roentgenol.*, 1931, *26:* 428–435.
5. CLARK, L. P., and ATWOOD, C. E. A report of cases of Landouzy-Dejerine myopathy (congenital), Thomsen's disease, and enchondroma of the hypophysis, and of other cases of rare types of muscular dystrophy and anteriopoliomyelitis, with remarks. *N. Y. med. J.*, 1907, *86:* 97–104 (see Case IV).
6. COHN, I. Dyschondroplasia. *Ann. Surg.*, 1916, *123:* 673–686.
7. COLE, W. H. Chondrodysplasia. *Surg. Gynec. Obstet.*, 1926, *42:* 359–365.
8. COOPER, A., and TRAVERS, B. Surgical essays. *Philadelphia: J. Webster*, 1821, xii, 409 pp. (see p. 131).

9. Ehrenfried, A. Multiple cartilaginous exostoses—hereditary deforming chondrodysplasia. *J. Amer. med. Ass.*, 1915, *64:* 1642–1646.
10. Ehrenfried, A. Hereditary deforming chondrodysplasia—multiple cartilaginous exostoses. A review of the American literature and report of twelve cases. *J. Amer. med. Ass.*, 1917, *68:* 502–508.
11. Farrell, M. J., Maloney, J. D., and Yakovlev, P. I. Morquio's disease associated with mental defect. *Arch. Neurol. Psychiat., Chicago*, 1942, *48:* 456–464.
12. Fisher, L. D., Parsons, C., and Cutting, C. C. Hereditary multiple exostosis. Review of the literature and report of a case with Horner-Bernard syndrome as a complication. *Permanente Found. med. Bull.*, 1945, *3:* 124–136.
13. Gibney, V. P. Multiple exostosis. *Med. Rec., N. Y.*, 1875, *10:* 300.
14. Gibney, V. P. Hereditary multiple exostosis; four cases, with remarks. *Amer. J. med. Sci.*, 1876, n.s. *72:* 73–80.
15. Graney, C. M. Hereditary deforming chondrodysplasia. Report of ten cases in one family. *J. Amer. med. Ass.*, 1939, *112:* 2026–2030.
16. Grollman, A. Dyschondroplasia (hereditary deforming chondrodysplasia). *Oxford Med.*, 1943, *4*, pt. 3: 487–499.
17. Guy's Hospital. Case of cartilaginous exostosis. *Lancet*, 1825, *8:* 91.
18. Hale, K. Hereditary deforming chondrodysplasia or multiple exostoses. Report of a father and two daughters showing similar multiple symmetrical exostoses and fifty other cases collected from the English literature since 1917. *Ann. Surg.*, 1930, *92:* 92–114.
19. Hunter, D., and Wiles, P. Dyschondroplasia (Ollier's disease): with report of a case. *Brit. J. Surg.*, 1935, *22:* 507–519.
20. Keith, A. Studies on the anatomical changes which accompany certain growth-disorders of the human body. I. The nature of the structural alterations in the disorder known as multiple exostoses. *J. Anat.*, 1920, *54:* 101–115.
21. Krause, G. R. Dyschondroplasia with hemangiomata (Maffucci's syndrome). Case report. *Amer. J. Roentgenol.*, 1944, *52:* 620–623.
22. Leucutia, T., and Price, A. E. Hereditary deforming chondrodysplasia. *Amer. J. Roentgenol.*, 1929, *22:* 338–345.
23. Mahorner, H. R. Dyschondroplasia. *J. Pediat.*, 1937, *10:* 1–26.
24. Nielson, J. L., Jr. Ollier's disease. Report of the first case with involvement of the optic nerve. *Bull. Los Angeles neurol. Soc.*, 1941, *6:* 104–114.
25. Oberndorf, C. P. A case of multiple exostoses coupled with syringomyelia. *N. Y. med. J.*, 1910, *91:* 479–483.
26. Ochsner, E. H., and Rothstein, T. Multiple exostoses, including an exostosis within the spinal canal with surgical and neurological observations. *Ann. Surg.*, 1907, *46:* 608–616.
27. Ollier. Exostoses ostéogéniques multiples. *Lyon méd.*, 1898, *88:* 484–486.
28. Percy, N. M. Multiple chondro-osteoma. *Surg. Gynec. Obstet.*, 1915, *20:* 619–621.
29. Reid, J. Disease of the spinal cord from an exostosis of the second cervical vertebra. *Lond. Edinb. Mcn. J. med. Sci.*, 1843, *3:* 194–198.
30. Reinecke, A. Ueber die Erblichkeit der multiplen Wachsthums-Exostosen. *Beitr. klin. Chir*, 1891, *7:* 657–672.
31. Rose, J., and Doolan, P. D. Hereditary multiple exostoses. *New Engl. J. Med.*, 1949, *240:* 799–801.
32. Ruggles, H. E. Dwarfism due to disordered epiphyseal development. *Amer. J. Roentgenol.*, 1931, *25:* 91–94.
33. Sanderson, G. H., and Smyth, F. S. Chondrodysplasia (Ollier's disease). A report of a case resembling osteitis fibrosis cystica. *J. Bone Jt. Surg.*, 1938, n.s. *20:* 61–67.
34. Stanley, E. A treatise on diseases of the bones. *Philadelphia: Lea & Blanchard*, 1849, 286 pp. (see pp. 212–216).
35. Stocks, P. Hereditary disorders of bone development. Part. I. Diaphysial aclasis (multiple exostoses), multiple enchondromata, cleido-cranial dysostosis. *The treasury of human inheritance.* London: Cambridge Univ. Press, 1925, *3:* 182 pp.
36. Stubenbord, W. D. Hereditary deforming chondrodysplasis. *South. med. J.*, 1945, *38:* 816–819.
37. Vanzant, B. T., and Vanzant, F. R. Hereditary deforming chondrodysplasia. *J. Amer. med. Ass.*, 1942, *119:* 786–790.

# MASSIVE CEREBRAL INFARCTION PRODUCING VENTRICULOGRAPHIC CHANGES SUGGESTING A BRAIN TUMOR

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Thrombosis of intracranial arteries is not ordinarily associated with a rise in intracranial pressure. Edema and swelling may occur with cerebral softenings for a period of time, but usually they do not produce symptoms of intracranial pressure. The following case presented a difficult clinical problem. While parts of the history suggested a vascular occlusion, other aspects aroused a strong suspicion of intracranial neoplasm. As the patient's condition became more precarious, it was felt that the latter diagnosis should be excluded. Procedures with the least risk were carried out first, but later it appeared mandatory that a more radical course be undertaken.

## CASE REPORT

No. 137453. E.C., a white female aged 59 years, was admitted because of inability to use the left arm and left leg. During a previous hospital stay in February, 1950, it had been disclosed that she had mild diabetes mellitus, mild arteriosclerosis, a blood pressure of 160/100, and a history of transient diplopia.

The present illness began about May 1950, when the patient experienced numbness and paresthesias in the tips of the fingers of the left hand. Shortly thereafter fine movements of the hand became impaired and she had difficulty in sewing. This became more pronounced with time and later she often dropped her fork while using it. Weakness of the left leg appeared during the following month and at times she had difficulty in walking and getting out of a chair. The night before admission, she attempted to get up from a chair but fell to the floor, almost completely paralyzed. After about 10 minutes voluntary motion re-appeared in the right arm and leg and with help she managed to stagger to bed, using the left leg slightly. During the night she was somewhat disoriented and attempted to get out of bed and again fell to the floor because of weakness. The next day there was complete left-sided paralysis, with facial involvement. The sensorium was intact. She was alert and able to make known her wants. Her daughter reported that the patient had lost 40 pounds during the past year and had not been following her diet properly.

*Examination.* She was a thin but well developed white woman, lying quietly in bed, who showed obvious loss of weight. B.P. 150/100; pulse 84; respirations 20, regular and even. There was abundant evidence of generalized arteriosclerosis. The optic discs were flat, well outlined and of good color, the vessels showing moderate arteriosclerosis. There were no visual field defects on gross tests. There was left facial paralysis of central type and the tongue deviated slightly to the right. Except for ability to flex the fingers slightly, the left arm and shoulder were paralyzed. The patient was able to raise and lower the left leg while lying in bed but movements were weak and could not be performed against gravity. There was no increase in tone. The reflexes on the left were hyperactive. Clonus in the left ankle, a Hoffmann reflex in the left hand, and Babinski response in the left foot were easily elicited. No gross sensory changes were present. Cerebellar tests could not be adequately carried out but there was nothing to suggest a cerebellar disturbance.

X-rays of the skull disclosed an osteoma in the left parietal region; this was regarded as benign and asymptomatic. The pineal was displaced to the left about 3 mm.

*Laboratory Data.* Urinalysis showed only a faint trace of sugar and no albumen. Fasting

blood sugar was 181 mg. per cent; blood urea was 24 mg. Hb., RBC and WBC were not remarkable; Wassermann was negative. Lumbar puncture was done; CSF pressure was 82 mm. of fluid; protein was 33 mg. per cent; Wassermann was negative; there were no cells.

The first impression was that the patient probably had a vascular accident. However, in view of the history of slow progression of symptoms, it was felt that she might have a neoplasm into which a hemorrhage had occurred.

*Course.* Since the patient was in fair condition, it was thought best to do an arteriogram. The percutaneous method was used. We were unable to force any dye beyond the junction of the carotid and middle cerebral arteries (Fig. 1).

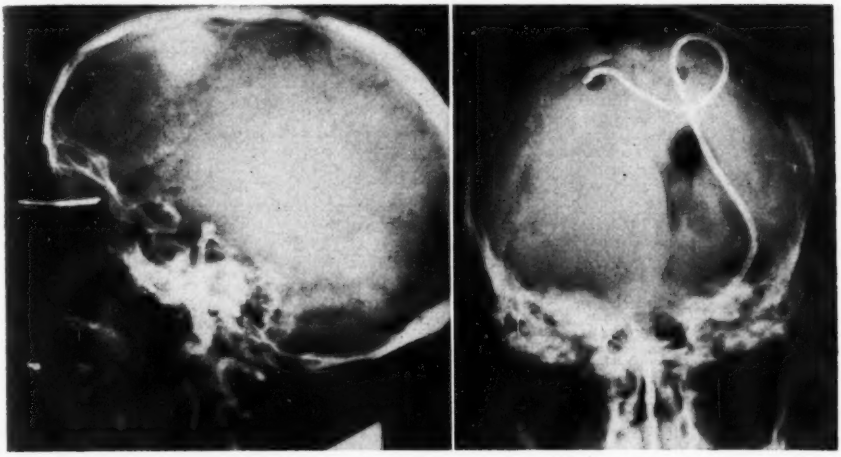

FIG. 1 (*left*). Right carotid arteriogram, showing thrombosis at junction of middle cerebral and carotid arteries. Note reflux filling of vertebral artery.

FIG. 2. (*right*). Ventriculogram, A-P projection, showing compression and deviation of right lateral and third ventricles.

Following this, the patient became very much worse. She recovered consciousness slowly from the small dose of pentothal given. The hemiplegia became more profound within a few hours. She lapsed into stupor but could be roused with difficulty. On the next day there was further deterioration and the right pupil became enlarged and fixed to light.

In view of the pronounced pineal shift, the diagnosis of neoplasm appeared as probable as that of thrombosis, so it was decided to perform ventriculography. Bilateral occipital trephines were done, during which time breathing stopped. The left ventricle was entered without difficulty and fluid gushed through the needle under considerable pressure, following which spontaneous respirations were resumed. There was a marked ventricular shift to the left suggesting a mass in the frontoparietal region of the right cerebral hemisphere. A massive thrombosis producing edema was considered but a large intracranial neoplasm seemed more likely (Figs. 2, 3 and 4).

*Operation.* A right-sided flap was turned down under local anesthesia. The brain was under moderate tension but almost entirely necrotic. The blood vessels in the Sylvian fissure were thrombosed along their entire course. A large part of the white matter of the frontal, parietal and anterior temporal regions was removed without causing any bleeding whatsoever. The anterior cerebral artery, too, was thrombosed along its complete length. There was no bleeding from the cortex until the region of the junction of the lateral and temporal horn was reached, where the brain is supplied by the posterior cerebral artery. The area of necrosis extended down into the basal ganglia and into the corpus callosum.

*Postoperative Course.* The patient's condition remained precarious and although she survived for approximately 48 hours, her course was downhill and she died without regaining consciousness. The right pupil during this time had again become equal to that on the left and once more responded to light.

*Postmortem Examination.* The internal carotid artery was thrombosed as it emerged from the cavernous sinus. The entire length of the right anterior cerebral and middle cerebral systems was completely occluded. A prominent cerebellar pressure cone was present. Multiple sections of brain showed softening which extended over almost the entire right hemisphere except for the portions of occipital lobe, posterior parietal and temporal lobes supplied by the posterior cerebral artery. The necrosis extended to the right basal ganglia and down into the mid brain. It was softening in this region that undoubtedly produced the final outcome.

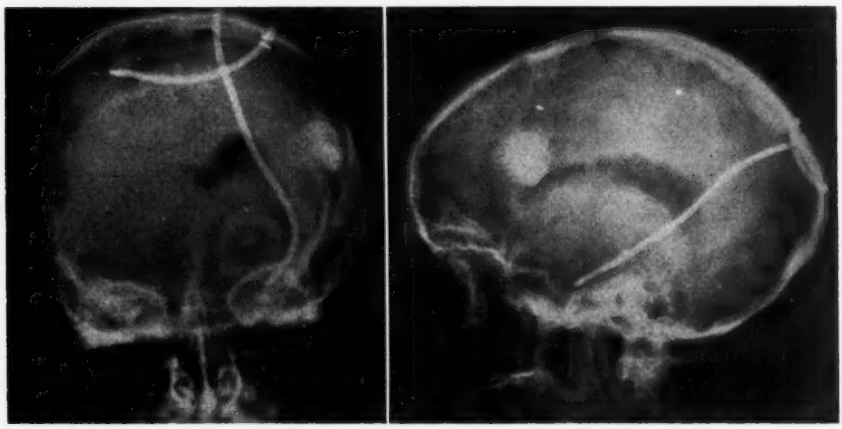

FIG. 3. (*left*). P-A projection showing obliteration of temporal horn and posterior portion of lateral ventricle. The third ventricle is markedly shifted and compressed.

FIG. 4 (*right*). This view shows normal left ventricle and benign osteoma of skull.

## DISCUSSION

This case is presented as an example of how an extensive thrombotic softening with swelling of the necrotic tissues may mimic a tumor. When the history, physical findings and x-ray studies appear to point toward a slowly developing intracranial neoplasm rather than a cerebrovascular accident, the problem of differential diagnosis is even more difficult. A hemianopsia was not present when the patient was first seen, but it must have developed later as the softening progressed. The changes in the eyegrounds seen in some cases of thrombosis of the internal carotid artery when the ophthalmic artery is also occluded, as noted by King and Langworthy,[1] were not present in this patient. At necropsy the thrombosis in the carotid had not extended that far inferiorly to involve the orifice of the ophthalmic artery.

From the clinical history one would suspect that the thrombosis was a slowly developing affair, at first producing mild symptoms until finally the last remnants of collateral circulation disappeared. There was no possibility of large parts of the hemisphere being supplied with blood since all the collaterals had been thrombosed. The edema resulting from the necrosis undoubtedly produced the signs of intracranial hypertension and exerted pressure on the hypothalamus and mid brain, causing additional softening in these areas. Although shift of the pineal was noted

in x-ray, lumbar puncture at the time showed a spinal fluid pressure of only 82 mm. of fluid. At operation 24 hours later, however, the ventricular fluid was under great pressure, so probably there was inadequate communication of the intracranial fluid with the lumbar spinal fluid. Despite the low pressure on lumbar puncture, there was adequate evidence of elevated intracranial pressure a few hours later. This was: (a) rapid deterioration of consciousness, (b) shift of the pineal to the left, (c) enlarged and fixed pupil on the right, which later became smaller and reacted to light after removal of brain tissue, (d) bulging of the right hemisphere on opening the dura, despite ventricular drainage, (e) respirations were restored almost immediately after ventricular puncture and were spontaneous for 48 hours after intracranial decompression.

Rarely has shift of the pineal been noted in cerebral vascular accidents, and often it is due to intracerebral hemorrhage rather than edema alone. Such a pronounced shift of the ventricular system as was noted in this case is unique in my experience. A perusal of the literature available does not reveal an exactly similar case although I am certain that the condition has probably been observed before. While the arteriograms indicated a thrombosis of the internal carotid artery, the ventriculographic findings made a neoplasm seem more likely. At operation the intracranial pressure produced a moderate herniation of cerebral tissue through the bony defect upon incising the dura, even after ventricular drainage had been established. The extensive necrosis and the complete absence of bleeding whenever an incision was made into the brain, confirmed the arteriographic findings.

Postmortem studies were considerably hindered since the brain could not be properly injected because of the extensive thrombosis and even after considerable hardening so much of it was necrotic that the extent of the softening into the mid brain and basal ganglia could not be precisely delineated. It could be established, however, that the posterior cerebral was adequately functioning, as were the cerebral arteries on the left side. Microscopic sections disclosed only necrosis. There was no evidence of a neoplasm. Sections from the main cerebral arteries of the right hemisphere confirmed the occlusion. The thrombi were of recent origin and showed no sign of organization.

## SUMMARY

The patient had sustained a thrombosis of the right internal carotid artery together with complete occlusion of the anterior and middle cerebral systems on the same side. The resulting arteriographic and ventriculographic changes are presented, and the difficulties in differential diagnosis between a vascular accident and a neoplasm are discussed.

## REFERENCE

1. King, A. B., and Langworthy, O. R. Neurologic symptoms following extensive occlusion of the common or internal carotid artery. *Arch. Neurol. Psychiat., Chicago*, 1941, *46:* 835–842.

# THE REPAIR OF LUMBAR AND CRANIAL MENINGOCOELE WITH TANTALUM GAUZE

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Not infrequently, the protrusion of the dura and arachnoid through a defect in either the vertebral arch or the cranium is encountered. Where no notable inclusion of neural elements exists, and no Arnold-Chiari malformation can be demonstrated, local surgical correction may be undertaken. The operative procedures usually consist of resection of the sac or its inversion into the canal, with an approximation of the edges of the dehiscence.

Where the defect is large, it may not be possible to effect a satisfactory primary closure, unless the sutures are placed under considerable tension—a frequent prelude to failure.

It may be necessary to borrow fascia from adjoining structures in the hope that, by imbrication, enough strength-in-depth may be gained to contain the variable

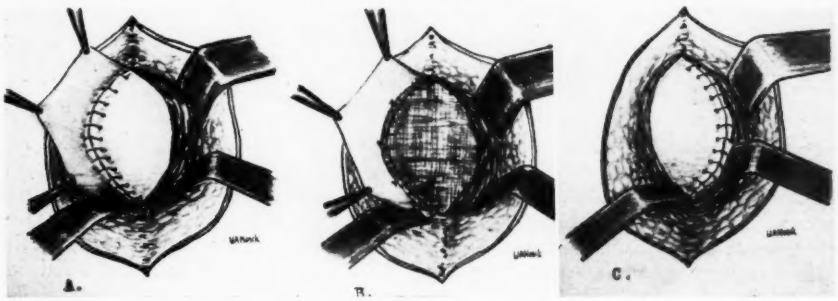

FIG. 1. (A) A fascial flap is sutured over the previously closed sac. (B) Tantalum gauze screen is sutured in place over the first fascial layer. (C) The tantalum gauze is covered with another fascial flap.

hydrostatic pressures. If the pressure is not effectively contained, a troublesome pseudomeningocoele may follow.

In this consideration, the problem was not unlike that encountered in the repair of recurrent, large abdominal herniae which have long plagued the general surgeons. Where it has not been possible to effect a primary approximation of the edges, many efforts were made over the years by ingenious surgeons to buttress the defect with metallic plates, wires, grids, nettings and meshes. Because these materials were uncomfortable to the patient or lacked the proper physical qualities for retention in the body, their use was discontinued.

In 1947, Throckmorton[2] submitted his results with tantalum gauze in the repair of herniae complicated by tissue deficiency. His studies, as well as those of Douglas,[1] indicated that the new connective tissue grew through the interstices of the gauze to form a very solid fibrous aponeurosis—a favorable situation where a firm wall

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is desired. Satisfactory repair was made of herniae where local tissue deficiency rendered the usual type of autoplastic repair impractical.

The analogy to the problem encountered in an occasional meningocoele repair seemed striking, particularly where the size of the defect or the attenuation of the neighboring fascia presaged the formation of a pseudomeningocoele or actual breakdown.

Accordingly, when an infant was encountered in whom such a large dehiscence existed after excision and closure of the sac, imbrication of the lumbar fascia over tantalum gauze was done. The procedure followed is shown in Fig. 1. The convalescence of this 7-week-old boy was uneventful. Subsequent roentgenograms revealed the gauze to be intact and in good position. The tissue under the incision and in the implant area seems thicker and more firm, the operative site being otherwise unremarkable.

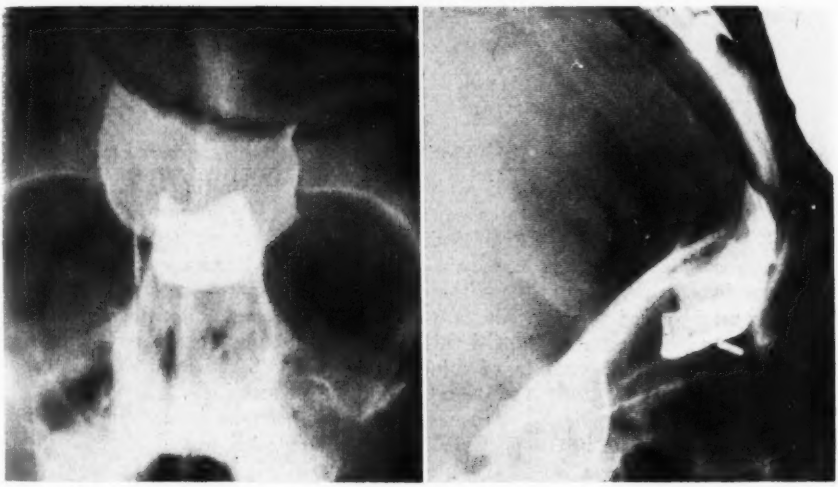

FIG. 2. Postoperative roentgenograms showing AP and lateral views of tantalum gauze supporting dura over cranial dehiscence.

Another problem of similar type, though in a different locale, was likewise treated using tantalum gauze in the repair.

In this 3-year-old boy, there was a large right nasal meningocoele. Through a frontal craniotomy the dura was stripped from the floor of the frontal fossa and the neck of the meningocoele isolated as it passed through a defect in the right cribriform plate.

The nasal extension was resected transnasally by Dr. P. M. Moore. The edges of the sac were clipped with metal clips and sutured. To prevent further herniation through the bony defect, where the pulsating dura was unsupported by bone, a strip of tantalum gauze was placed across the area and another was sutured to the dura to prevent any possible shifting. A rather solid platform for the dura was thus provided. The convalescence was entirely uneventful. Approximately 1 year postoperatively, his condition remains good, there being no evidence of recurrence or rhinorrhea. The roentgenograms show the position of the tantalum screen postoperatively (Fig. 2).

## CONCLUSIONS

1. When local tissue deficiency precluded a successful autoplastic repair in a patient with a simple lumbar meningocoele, the imbrication of lumbar fascia over tantalum gauze effected a solid repair.

2. The closure of a nasal meningocoele is reported using tantalum gauze to cover the cranial dehiscence, and to support the overlying dura.

## REFERENCES

1. Douglas, D. M. Repair of large herniae with tantalum gauze. An experimental and clinical study. *Lancet*, 1948, *254*: 936–939.

2. Throckmorton, T. D. Tantalum gauze in the repair of hernias complicated by tissue deficiency. A preliminary report. *Surgery*, 1948, *23*: 32–46.

# EXTRADURAL CEREBELLAR HEMATOMAS

## REPORT OF TWO CASES*

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(Received for publication March 30, 1951)

Extradural hematoma is a lesion almost universally resulting in fatality when not attacked surgically, yet recovery should be the rule in properly managed cases. The symptom complex of such lesions occurring above the tentorium is generally well recognized and treated. On the other hand, only 7 cases were found in the literature in which extradural hematoma occurring below the tentorium had been recognized and cured to date. The successive occurrence of 2 such cases without localizing cerebellar signs prompted this report. Both cases terminated fatally. It is hoped this experience may be of value in raising the "suspicion index" in cases where seemingly minor trauma to the occiput has been sustained.

In 1901, Wharton[8] reviewed 70 cases of intracranial venous sinus wounds, finding 8 instances of bleeding in the posterior fossa. Anderson,[1] however, in reporting a successfully treated case, noted that no examples of this lesion had appeared at the Los Angeles County Hospital during the preceding 14 years, where an average of 2000 head injuries are seen each year. Gurdjian and Webster,[5] Kessel,[6] Turnbull,[7] Coleman and Thomson,[3] Grant and Austin,[4] Anderson,[1] and Bacon[2] have each reported 1 case of extradural cerebellar hematoma successfully evacuated by operation.

Head trauma, particularly a blow to the occiput, usually initiates the lesion. The probable mechanism of injury is a laceration of some portion of the lateral sinus, with subsequent escape of blood downward into the potential epidural space of the cerebellar fossa. A fracture line will most generally be found crossing the lacerated sinus. It would appear that extradural cerebellar clots may be formed acutely or may accumulate more slowly.

Headache, stiff neck, vomiting, and irritability are generally found in those patients not unconscious from the blow. In acute cases the early onset of coma may preclude neurologic evidence which would otherwise correctly direct one's attention to the posterior fossa. Such individuals may exhibit hypotonia, positive

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Babinski signs and little else before spontaneous respirations cease. Should bleeding progress more slowly, the drowsy, though conscious patient may exhibit papilledema, nystagmus or ataxia. It should be emphasized that the symptomatology of these clots is notoriously unreliable. Additional neurologic findings, such as hemiparesis, unequal deep reflexes and unequal pupils may erroneously lead the observer to other intracranial localization. Such was the situation in the first instance of such a clot seen by the author.

## CASE REPORTS

*Case 1.* J.L., a 20-year-old white female, was injured when she was thrown from a horse on Mar. 29, 1950, and probably kicked in the back of the head. When carried to a nearby ranchhouse she was unconscious, but soon could respond to commands. She complained of severe headache, and pain in the neck. The family physician was called, and found the patient semiconscious, with a stiff neck, equal pupils, and vital signs that were within normal limits. Codeine was left to control the pain.

She failed to improve and was taken to the local hospital some 12 hours later. A lumbar puncture was done, the fluid being reported grossly clear, and the pressure "normal." Portable lateral x-rays of the skull revealed no fracture. The patient continued to moan with pain and thrash about in bed. Forty hours after injury she was transferred to a hospital in this city, because her local physician felt she did not seem to be doing well.

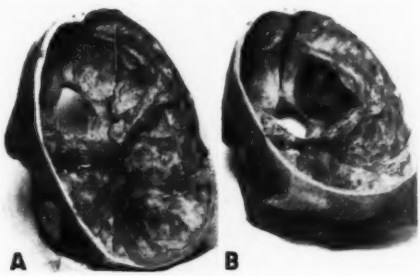


FIG. 1. Reconstruction to show site of fracture (A) and extradural clot (B) in left cerebellar fossa.

*Examination.* The patient was comatose, lying restlessly in bed and moving all extremities equally. Painful stimuli elicited appropriate defense reactions. No abrasions nor lacerations of the scalp were noted, though a Battle's sign was present on the left. Attempted flexion of the head demonstrated boardlike resistance of the neck. There was no bleeding from the cranial orifices. The pupils were equal and reacted to light. The eyegrounds were normal. The deep tendon reflexes were equal, but there was a positive Babinski on the left. BP 116/78, pulse 86, respirations 22, temperature 99.6°.

*Course.* Feeling that the patient was suffering from a left basal skull fracture with cerebral contusion, and subarachnoid bleeding, a conservative course was decided upon. Sedation was withheld in order that changes in the state of consciousness and vital signs could be followed more accurately. Restlessness continued for 2 hours. At this time, and for no apparent reason, the patient sat upright in bed, became cyanotic and fell backward with markedly irregular pulse and respirations. Within 5 minutes she was dead.

*Autopsy.* There was a 7 cm. linear fracture curving from the left lateral sinus to the left jugular foramen (Fig. 1). Associated with the fracture site was an extradural collection of liquid blood and clot estimated at between 30 cc. and 40 cc. in amount. The adjacent left lobe of the cerebellum was moderately compressed and there was herniation of the cerebellar tonsils, more marked on the right side. A contrecoup small linear fracture of the right frontal region with minimal subdural hemorrhage was present. There were contusions and superficial areas of laceration of the tip of the right frontal and parietotemporal lobes with small areas of subarachnoid hemorrhage. Multiple sections through the entire brain showed only moderate edema of the brain stem and slight softening of the cerebellum. There was no intraventricular bleeding.

This patient probably could have survived, had the proper diagnosis been sus-

pected and surgery instituted. It was not more than 2 months later when my only other encounter with an extradural cerebellar hematoma occurred.

*Case 2.* J.H., a 25-year-old white male, fell from the rear end of a slowly moving truck, striking the back of his head on the pavement. He did not lose consciousness, but was taken to the hospital because he complained of increasingly severe headache. When examined by his family doctor one-half hour later, the headache had become more severe and was accompanied by dizziness and nausea. Although examination at that time was negative except for an occipital abrasion of the scalp, skull x-rays disclosed a linear right-sided occipital fracture. The patient was put to bed in the hospital, and because of extreme restlessness sedation was given. Three hours after injury the nurse on rounds found the patient had stopped breathing and was markedly cyanotic. Artificial respiration was instituted and the physician called. Examination revealed all extremities to be flaccid and no reflexes could be elicited. The right pupil was widely dilated, and neither pupil reacted to light. Nevertheless the pulse was full and strong; temperature and blood pressure were essentially normal. The patient was placed in a respirator and observed for one-half hour; when his condition then showed no apparent deterioration, the local physician called the author, who saw the patient some 3 hours and 150 miles later. On examination, findings remained essentially unchanged, though no spontaneous respirations had occurred. Although surgery seemed futile, it was the impression that possibly evacuation of an extradural clot might reverse what seemed surely would be a fatal outcome.

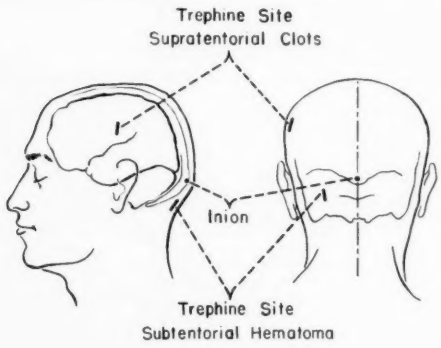


FIG. 2.

*Operation.* The entire head was prepared and a burr hole placed in the right temporal region, where it was thought such a clot most likely would be found. A thin layer of subdural blood was encountered, but not enough to be of clinical significance. The left temporal region was trephined and the findings here were negative. As on the right, the brain continued to exhibit markedly increased pressure. Accordingly, bilateral suboccipital perforator openings were made, and on the right side a large extradural cerebellar clot was encountered beneath the site of the fracture, extending both above and below the lateral sinus. The bleeding seemingly originated from a laceration of the sinus near the torcular. After evacuation of the clot the compressed cerebellum reexpanded.

*Course.* Although the patient improved slightly from the standpoint of his pulse and blood pressure, no spontaneous respiration occurred. Temporary improvement, however, was followed by his death some 24 hours later. Autopsy was not permitted.

It is obvious that the rapid accumulation of blood between the dura and skull presents the surgeon with a genuine emergency. Despite the infrequency of such lesions below the tentorium, their immediate recognition—or at least suspicion thereof—is paramount.

Given an individual who has sustained trauma to the occiput, and complains of headache, suboccipital pain and vomiting, who has an occipital fracture, and who exhibits stiff neck, drowsiness and irritability, exploratory perforator openings should be placed over the cerebellum, whereby an extradural clot may be detected. Fig. 2 suggests the location of such an opening. Should a clot be uncovered, the incision can be enlarged and craniectomy carried out until the source of bleeding is

identified and controlled. Though a normal extradural space may be disclosed in the majority of cases, the rare patient with such a clot will be saved from irreversible respiratory failure.


REFERENCES

1. Anderson, F. M. Extradural cerebellar hemorrhage. Review of the subject and report of a case. *J. Neurosurg.*, 1949, *6:* 191–196.
2. Bacon, A. Cerebellar extradural hematoma. Report of a case. *J. Neurosurg.*, 1949, *6:* 78–81.
3. Coleman, C. C., and Thomson, J. L. Extradural hemorrhage in the posterior fossa. *Surgery*, 1941, *10:* 985–990.
4. Grant, F. C., and Austin, G. M. Evacuation of traumatic extradural hemorrhage from the posterior fossa. *Ann. Surg.*, 1949, *130:* 963–966.
5. Gurdjian, E. S., and Webster, J. E. Extradural hemorrhage. A collective review of the literature and a report of 30 cases of middle meningeal hemorrhage and 4 cases of dural sinus hemorrhage treated surgically. *Int. Abstr. Surg.*, 1942, *75:* 206–220.
6. Kessel, F. K. Cerebellar extradural haematoma. *J. Neurol. Psychiat.*, 1942, n.s. *5:* 96–100.
7. Turnbull, F. Extradural cerebellar hematoma. A case report. *J. Neurosurg.*, 1944, *1:* 321–324.
8. Wharton, H. R. Wounds of the venous sinuses of the brain. An analysis of seventy cases. *Ann. Surg.*, 1901, *34:* 81–110.


## ARTERIOGRAPHY

### A USEFUL ADDITION TO THE TECHNIQUE


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Carotid artery injection with the needle attached directly to a syringe is not entirely satisfactory. In this Clinic the use of polyethylene tubing between the syringe and needle (Fig. 1) has solved some of the problems and proven very helpful over a period of a year, during which time some 200 percutaneous carotid arteriograms have been done.

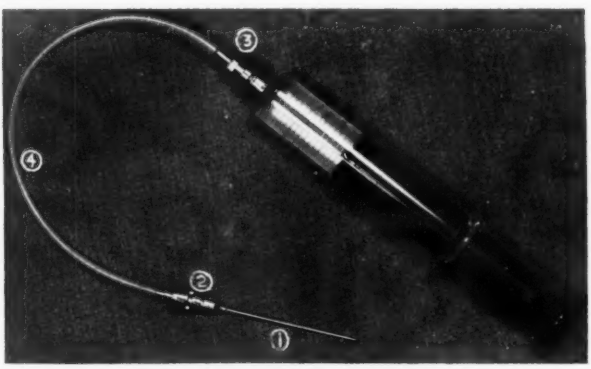


Fig. 1. (1) Primary insertion of No. 18 needle into artery with needle attached to syringe. (2) After insertion, the polyethylene tubing is connected to the needle with a Luer-Lok adapter (Lemon 608/L†). (3) The polyethylene tubing is connected to the syringe with a standard adapter (Lemon 80/L†). (4) Polyethylene tubing, 12–14″ long, with inside diameter of .065″ and outside diameter of .098″.

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† Becton-Dickinson Co., Rutherford, New Jersey.

The flexible polyethylene tubing allows the needle in the artery to remain stationary in spite of any movement of the syringe during the injection. The operator's hands are not in the zone of high radiation. With the syringe full of saline the blood can be seen moving to and fro in the tubing, enabling the operator to be sure the needle is still in place between the injections of diodrast. Sterilization is effected by soaking the adapters and tubing in 1:1000 aqueous Zepharin for 24 hours. The tubing is very flexible and withstands the pressure of injection easily. The necessary adapters are easily inserted after the tubing has been heated in boiling water. The inside diameter is enlarged by stretching with a mosquito forcep. The joint is made permanently secure by immediate immersion into cold water.

# SURGICAL TREATMENT OF ACOUSTIC TUMORS*

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(Received for publication April 20, 1951)

I think my description of the mode of operating, and of the anatomy of the parts concerned, clear enough, to enable any good anatomist, possessing the judgment requisite for a surgeon, to operate with safety. I hope no operator of any other description may ever attempt it. It is my most ardent wish, that this operation may remain, to the mechanical surgeon, for ever incomprehensible. Such have been the *bane* of the science; intruding themselves into the ranks of the profession, with no other qualifications but boldness in undertaking, ignorance of their responsibility, and indifference to the lives of their patients; proceeding according to the special dictates of some author, as mechanical as themselves, they cut and tear with fearless indifference, utterly incapable of exercising any judgment of their own in cases of emergency; and sometimes, without possessing even the slightest knowledge of the anatomy of the parts concerned.

EPHRAIM MCDOWELL, M.D.—1819.

ONE of the outstanding advances in the surgical management of intracranial tumors that has occurred in recent years has been in the handling of acoustic neurinomas. These have always been difficult lesions to treat satisfactorily. In the past the surgeon has been particularly disturbed by the high mortality that attended the removal of an obviously benign, encapsulated, well localized tumor. He was if anything even more perturbed by the fact that many of the patients who survived the operation were incapacitatingly disabled and many soon suffered a regrowth of the tumor which demanded another operation with even greater risks to life and well being. The late Walter Dandy, in an effort to improve the poor results that so commonly followed partial removal of these tumors, advocated complete extirpation as long ago as 1922.[5,6] However, his suggestions did not meet with general acceptance. Many surgeons were dissuaded from following his example by the high mortality that attended his earlier operations and by the fact that a complete facial paralysis always occurred. Olivecrona was one of those who early saw the wisdom of Dandy's recommendations and published his technical procedures in 1934.[12] Later studies of larger numbers of cases confirmed the feasibility of the total extirpation of these tumors by demonstrating not only that the mortality need not be higher with total extirpations than with partial ones, but that the end-results were distinctly better (Dandy,[8] Horrax and Poppen,[11] Olivecrona[9,13]). This was true not only because recurrence was impossible but because the postoperative disability was usually less severe with a total extirpation than it was with a partial one.

In spite of the growing number of publications indicating the desirability of total as compared with partial extirpation there are many neurological

* Presented before the Interurban Neurosurgical Society, Chicago, Illinois, February 24, 1951.

surgeons who still cling to the older technic. In the main they are deterred from adopting the more radical procedure because of the operative mortality, which is often quoted as being in the neighborhood of 30 per cent. These surgeons have not stopped to realize that such a high mortality was typical only of the earlier experiences of these pioneers. More recently several surgeons have reported rather large series of cases with operative mortalities of approximately 10 per cent (Dandy, Olivecrona, Horrax and Poppen).

In my own limited experience, since adopting the procedure of total extirpation of acoustic neurinomas in 1939, the operative mortality has not been higher. The operative technic that I have used is not original with me.† I adapted the unilateral linear incision to the removal of these tumors after having learned to use it for section of the 8th or 9th cranial nerves from Dr. Glen Spurling and Dr. Winchell McK. Craig.[4] Certainly this technic is used by some other surgeons and yet it is obvious that many are not aware of it and are not giving their patients the benefit of these methods of treatment. It is for no other reason that I have presumed to outline the method that I have found to work most successfully. I shall discuss it briefly and endeavor to present it primarily by means of illustrations.

It has been my practice to place my patients face downward in the cerebellar head-rest designed by Adson and modified by Bailey.[2] The table is tipped with the head upward to an angle of about 30 to 40° with the horizontal. I have used the sitting or upright position and have not cared for it because of the difficulties of combatting vascular collapse and the dangers of air-embolus. I prefer to anesthetize my patient with ether. Undoubtedly these tumors can be removed under local anesthesia, as Olivecrona advocates. Occasionally I have used such anesthesia, particularly in debilitated patients or others in whom I thought the ether anesthesia too great a risk, but, by and large, operating upon conscious patients in this position and for the long periods not infrequently necessary for the total extirpation of an acoustic neurinoma is a very tiring and painful procedure to which I do not care to subject my patients.

In my opinion the linear incision is of the greatest importance to the success of the operation. Dandy introduced the unilateral approach in 1934[7] but he always used the curved or inverted "V" incision. This incision produces a flap of scalp and muscle which is in the surgeon's way when it is turned down and interferes with good visualization of the lower part of the operative field. The transverse incision, both curved and horizontal, and the old crossbow incision of Cushing provide far more exposure than is needed, and require much more time to make and far more time to close. They are never required when an adequately localized acoustic neurinoma is being operated upon, although the curved incision from mastoid tip to mastoid tip is still very useful in operations upon tumors of the posterior fossa (acoustic neurinomas or otherwise) that can not be localized accurately. Furthermore, as

† Horrax has very recently (1950)[10] published a brief outline of his technic. It appears to be practically identical with that which is described here.

with the unilateral flap, the reflected mass of skin and muscle is a serious obstruction to the adequate exposure of the regions inferior and lateral to the cerebellum. The osteoplastic flap of Bailey for exposing one half of the cerebellar fossa is an extensive time-consuming exposure. It provides a very satisfactory exposure but if the lateral sinus is ligated, and it and the tentorium are incised, as Bailey originally advocated, the risk of interference

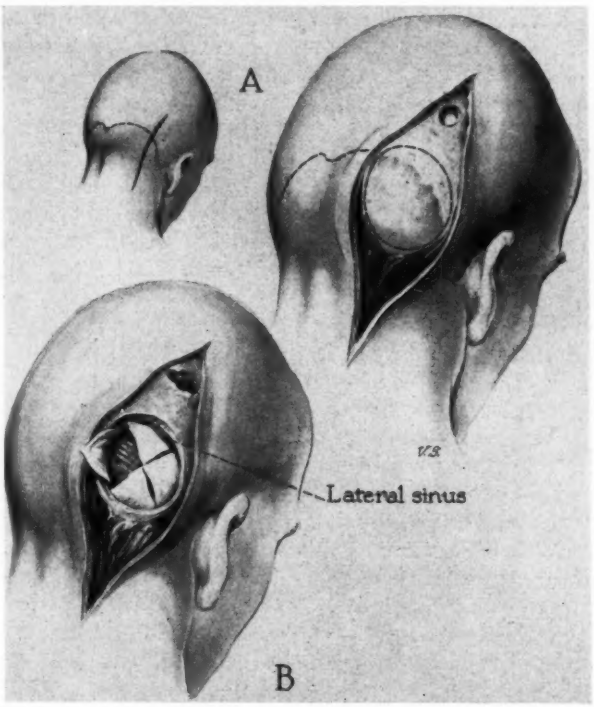


FIG. 1. (A) Linear incision just medial to the mastoid process. Burr-hole for ventricular puncture. Incision and separation of the neck muscles. Operative defect in the bone outlined with broken line. (B) Frazier needle in place in ventricle. Lower edge of lateral sinus exposed. Cruciate incision in the dura mater.

with venous circulation is considerable and seldom justifiable. The osteoplastic flap of Naffziger for approaching the posterior fossa through the tentorium from the region of the occipital lobe provides a good exposure of the superior surface of the cerebellum but is much more time-consuming and extensive than the exposure outlined here.

By extending the linear incision (Fig. 1) above the superior nuchal line a burr-hole can be made over the occipital lobe, and the lateral ventricle punctured and allowed to drain throughout the operation. This should be

done in all operations for tumors of the posterior fossa but is seldom necessary in operations for section of cranial nerves.

The linear incision should be made well lateral—just medial to the mastoid process. The insertion of the neck muscles at the superior curved line should be incised and the muscles stripped to either side from the under surface of the occipital bone. The wound edges should then be separated and held in place with a simple type of self-retaining retractor. It is important that the posterior part of the mastoid process be exposed and that the exposure be carried well down on the under surface of the occipital bone. It is the lateral and inferior parts of the exposure that are the most important. It is not necessary to open the foramen magnum. The burr-hole in the under surface of the occipital bone should be enlarged to about 3.5 to 4 cm. in diameter. The opening should extend as far laterally and downward as possible. The surgeon should have no hesitancy about opening some of the cells on the posteromedial edge of the mastoid unless there is a history or evidence of infection there. Superiorly the lower part of the lateral sinus should be exposed. The dura mater is then incised in a cruciate manner and the four resulting flaps are reflected out of the way and held in place by sutures.

It is well then to slip a ribbon-retractor medially, expose the lateral edge of the cisterna magna and open it to allow cerebrospinal fluid to escape. The surgeon then should confirm the existence of an acoustic neurinoma. Having done so, the lateral part of the cerebellar hemisphere overlying the tumor should be amputated (Fig. 2). Doubtless it is possible to expose these tumors by retracting the cerebellum but the trauma to the cerebellum and the compression of the contents of the posterior fossa which result are far more hazardous than the removal of this cerebellar tissue. The patient soon compensates for its loss, whereas the edema and hemorrhage which occur in the tissues if the cerebellum is merely retracted may easily defeat the surgeon or result in permanent changes in the cerebellum that are more disabling than the simple, limited amputation. In my opinion the linear incision and the amputation of the lateral part of the cerebellar hemisphere are the two most important steps in securing an adequate exposure, without which a satisfactory result cannot be obtained.

After this amputation has been completed the lateral surface of the tumor will be well exposed. If one is fortunate enough to encounter an arachnoidal cyst overlying the tumor, its evacuation will greatly aid in the exposure of the tumor and in separating it from the cerebellum. Often, however, there is no such cyst. The presenting capsule of the tumor should be incised and the interior of the tumor removed piecemeal (Fig. 3). Not infrequently this is associated with considerable hemorrhage unless one simultaneously cauterizes the tissue with the Bovie high-frequency electrical surgical unit and applies suction. For this purpose we have found the combination suction-cautery unit described with Oberhill[3] a most useful instrument. One, of course, also uses various spoons and small rongeurs for this piecemeal extirpation. When enough of the interior of the tumor has been removed to permit

the capsule to collapse he can begin to separate the tumor from the surrounding structures. First the 9th, 10th and 11th cranial nerves should be identified at the lower pole of the tumor. They should be gently separated from it and carefully protected by a cotton pledget placed over them. Then as the

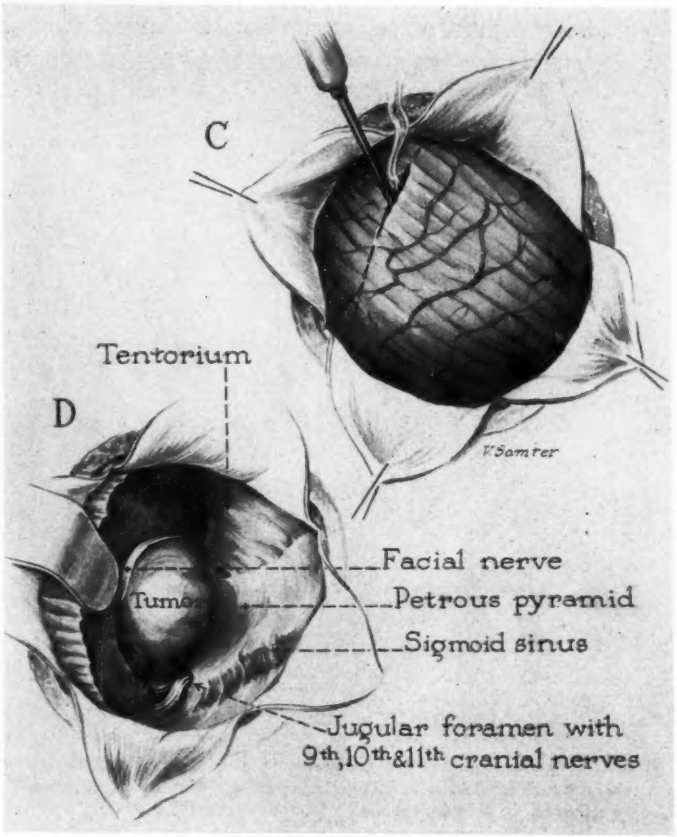


FIG. 2. (C) Incision in cerebellar hemisphere preparatory to amputation of lateral part. (D) Amputation completed. Lateral surface of tumor exposed. Facial nerve in unusual position dorsal to the tumor. The 9th, 10th, and 11th cranial nerves lie beneath the lower pole of the tumor. Tentorium, petrous pyramid and sigmoid sinus are visualized.

capsule is further mobilized one should search carefully for the facial nerve. It may be identified by electrical stimulation if necessary. This nerve is most commonly located on the under surface of the tumor and is often very difficult to identify. I have been able to identify it and preserve it most often when it has been located on the upper surface of the tumor. The nerve will be elongated and flattened, and will lie in a layer of arachnoidal tissue. Of

course, it is not always possible to spare it and I have not been as successful as Olivecrona, who preserved the nerve in 69 of his 300 cases, or 33 per cent of those in which a total extirpation was made. However, I am convinced that with care and experience anyone can improve his results in preservation of this important nerve.

As one gradually separates the capsule from the surrounding tissue he

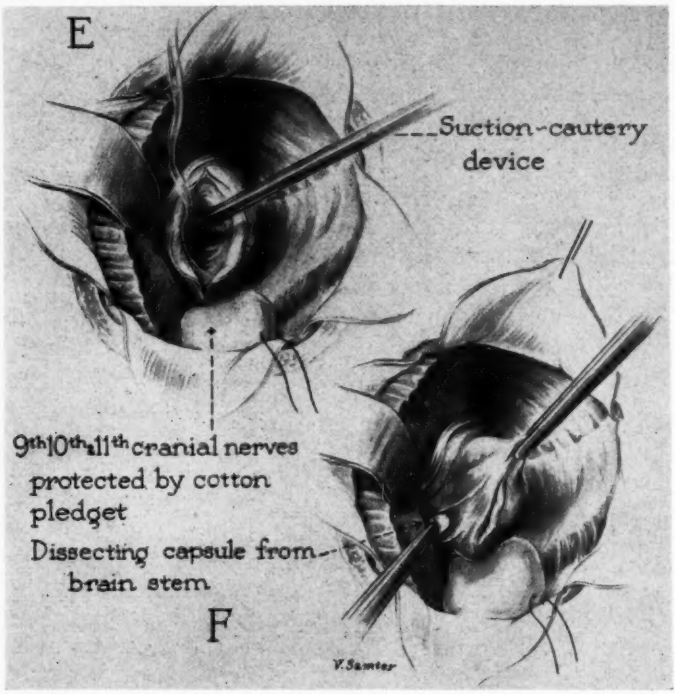


FIG. 3. (E) Tumor has been incised and the interior is being removed with the cautery-suction unit. The 9th, 10th, and 11th cranial nerves have been covered and protected with cotton. (F) The interior having been removed, the capsule is gradually separated from the brain.

will repeatedly find it necessary to return to the interior of the tumor and remove more of the inner mass. Soon the brain stem will begin to appear at the lower end of the tumor. This separation of the tumor from the brain stem should always be carried out from below upward. Fortunately the two are not particularly adherent in many cases and if the surgeon is patient and painstaking the separation can be accomplished with relatively little trauma to the neural axis. It is of the greatest importance that it should be. It is also important that the blood supply of the pons not be damaged, as Atkinson[1] has shown. If possible, no arteries should be clipped except those actually

entering the tumor. The cautery should not be used in this region and veins should be controlled with gentle packing and with "gelfoam." As the dissection progresses one will finally separate the tumor from the 5th nerve. Unfortunately it is often not possible to visualize this nerve until the separation is made. Accordingly the nerve may be torn or injured in the process. In this same region it is not uncommon to find a small projection of tumor which

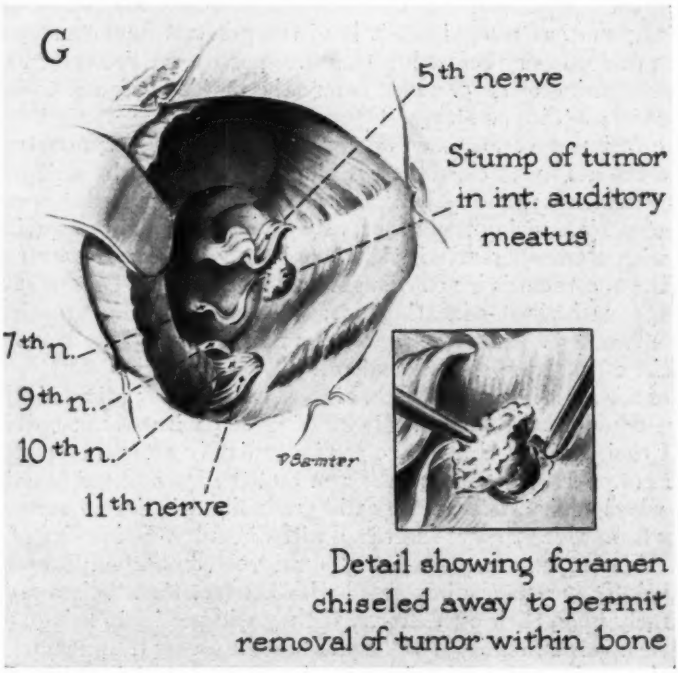


FIG. 4. (G) The tumor has been completely removed except for the tuft in the internal auditory meatus. The 5th, 7th, 9th, 10th and 11th cranial nerves have all been preserved. Finally, the lateral edge of the internal auditory meatus is chiseled off and the nodule of tumor removed.

extends upward through the incisura of the tentorium alongside the midbrain. This nodule must be removed but two dangers must be avoided. The brain stem must not be injured, and if the vein that enters the petrosal sinus at this point is torn it must be promptly controlled. In cases where this nodule is large the tentorium can be incised into the incisura (without disturbing the lateral sinus in any way). This should be done unhesitatingly if it is necessary but, fortunately, it seldom is.

After the great bulk of the tumor is removed one will usually find a small tuft of tumor projecting from the internal auditory meatus (Fig. 4). This must be removed in order that no remnant be left behind which may later

grow and again produce symptoms. If this bit of tumor is curetted out of the foramen or is removed with the electrosurgical unit, the facial nerve will most likely be destroyed. If we have been fortunate enough to preserve the facial nerve up to this point it is our practice to follow the procedure first advocated by Dandy. The lateral margin of the meatus is removed with a gouge or chisel, thus exposing the extension of the tumor down into the canal. It is then usually possible to remove the tumor and spare the facial nerve.

As everyone has recognized, it is of the greatest importance that the wound be perfectly dry before it is closed. A postoperative hemorrhage may give little warning of its presence before the patient is found to be in extremis or to have died suddenly.

If the facial nerve has been destroyed, the tone and symmetry of the face, and the ability to close the eye should be restored by doing a spinal accessory-facial anastomosis. Until this recovery has occurred the eye should be protected by suturing the lids or, as we commonly do, by providing the patient with a transparent, air-tight, conical eye-shield. However, merely making the anastomosis is not enough. The patient must be taught and encouraged to persist in re-educating his face to use this new innervation to the greatest advantage. This can be best accomplished by repeated, and persistent exercise of the face before the mirror.

One of the most important parts of the care of these patients is the postoperative rehabilitation. Practically all of these patients have considerable ataxia of their ipsilateral arm and leg immediately after the operation. If they are not encouraged to use the arm and the leg and are permitted to adopt a wheel-chair existence they will gradually drift into a state of total disability from which they are salvaged with difficulty. The feeling of despair which confronts many of these patients must be combatted. They must be encouraged. They must be impressed with the fact that their recovery depends largely upon their own efforts. If they will persist in using and exercising their upper extremity it will again become a very useful member. One of my patients who had a right-sided neurinoma is again using his right hand, carrying on his occupation as a painter and carpenter. Another uses hers successfully as a seamstress. Immediately after recovery from the operation many of these patients cannot walk. However, persistent effort first with someone else's help, later with a cane and finally unaided will almost always give gratifying returns. These improvements come slowly. The patient must be forewarned of this. He must be told that his recovery will require weeks and months. But he must be assured that he will walk and he will use his arm again if he is persistent. Such results, however, require the unremitting efforts of the surgeon, the patient's family and, most important of all, the patient himself. No one must be lulled into feeling that an adequate job of rehabilitation is being done if the patient sees a physiotherapist once a day and has some passive manipulation, massage, and a few baths. Only the patient is with his affected extremities 24 hours out of the day. He must be

taught, urged, and if necessary, made to manipulate, exercise and make every effort to use the affected arm and leg almost constantly.

## SUMMARY

In spite of various experiences demonstrating the superiority of total extirpation over partial or intracapsular extirpation the incomplete, inadequate operation is still performed in far too many cases. An operative technic for the total extirpation of acoustic neurinomas is described and illustrated. It has proved highly satisfactory over the past 12 years. It can be executed with a low mortality, with restoration of the patient to good health, able to practice his occupation and support himself and his family in a majority of cases. It is possible to preserve the facial nerve in some instances.

## REFERENCES

1. Atkinson, W. J. The anterior inferior cerebellar artery. Its variations, pontine distribution, and significance in the surgery of cerebello-pontine angle tumours. *J. Neurol. Neurosurg. Psychiat.*, 1949, n.s. *12:* 137–151.
2. Bailey, P. Concerning the technic of operation for acoustic neurinoma. *Zbl. Neurochir.*, 1939, *4:* 1–5.
3. Bucy, P. C., and Oberhill, H. R. Combination suction-cautery tip for use in neurological surgery. *J. Neurosurg.*, 1947, *4:* 545–546.
4. Craig, W. McK., and Shelden, C. H. Tumors of cranial nerves. In: *Surgical treatment of the nervous system.* F. W. Bancroft and C. Pilcher, Ed. Philadelphia: J. B. Lippincott Co., 1946, 534 pp. (see pp. 132–153).
5. Dandy, W. E. An operation for the total extirpation of tumors in the cerebello-pontile angle. A preliminary report. *Johns Hopk. Hosp. Bull.*, 1922, *33:* 344–345.
6. Dandy, W. E. An operation for the total removal of cerebellopontile (acoustic) tumors. *Surg. Gynec. Obstet.*, 1925, *41:* 129–148.
7. Dandy, W. E. Removal of cerebellopontile (acoustic) tumors through a unilateral approach. *Arch. Surg., Chicago*, 1934, *29:* 337–344.
8. Dandy, W. E. Results of removal of acoustic tumors by the unilateral approach. *Arch. Surg., Chicago*, 1941, *42:* 1026–1033.
9. Givré, A., and Olivecrona, H. Surgical experiences with acoustic tumors. *J. Neurosurg.*, 1949, *6:* 396–407.
10. Horrax, G., Olivecrona, H., Pennybacker, J. B., Cairns, H., and Northfield, D. W. C. Symposium on the results of operations on acoustic neuromas. *J. Neurol. Neurosurg. Psychiat.*, 1950, n s. *13:* 268–279.
11. Horrax, G., and Poppen, J. L. Experiences with the total and intracapsular extirpation of acoustic neuromata. *Ann. Surg.*, 1939, *110:* 513–523.
12. Olivecrona, H. Technik und Ergebnisse der Radikaloperation bei Acusticustumoren *Arch. klin. Chir.*, 1934, *180:* 445–448.
13. Olivecrona, H. Acoustic tumours. *J. Neurol. Psychiat.*, 1940, n.s. *3:* 141–146.

# EXPERIMENTAL EVALUATION OF CEREBRAL ANGIOGRAPHY*

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CEREBRAL angiography was introduced in 1927 by Moniz.[13] With accumulating experience it has become essential in the diagnosis of surgical intracranial vascular lesions and is also assuming great importance in the diagnosis of expanding, intracranial lesions.

One deterrent to its more universal use is the occurrence of complications attributed to the toxic effects of the contrast media.[5,7,9,17]

In this laboratory, an extensive search has been undertaken for compounds that will so alter cerebral permeability as to allow staining of the cerebral tissues by such dye substances as trypan blue, disulphine blue, and sodium fluorescein. One such substance proved to be Diodrast. In view of clinical implications, detailed studies of this effect were done and are the subject of this report.

## METHOD AND MATERIALS

Stock rabbits under 1 per cent pentobarbital anesthesia were the test animals.

(A) A control group of animals (1–18) were subjected to the basic procedure as described below (B) except that normal saline at the same injection rates was substituted for Diodrast injection.

(B) Animals 19–46. The right carotid artery was isolated and a cannula was inserted. Continuous saline was injected to prevent clot formation. A water manometer was placed in the system of tubing through which injection is made so that the arterial pressure could be observed at any time. A measured amount of 70 per cent Diodrast† was injected into the artery; the duration of injection was recorded. The force of injection was so controlled that normal arterial pressure was not exceeded. Three minutes after the completed injection, the indicator dye (trypan blue, disulphine blue, or sodium fluorescein) was given intravenously and the animals were then sacrificed by cardiac section at varying time intervals. The brain was removed, examined, often photographed, and sections were taken for microscopic study. When the test agent was sodium fluorescein, the brain was examined and photographed under ultraviolet light, as described by Moore.[16]

(C) Animals 47–57 were subjected to the same procedure except:

(1) Only Diodrast from a single batch‡ which had consistently been injurious to animals in group A was used.

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† Iodopyracet (Diodrast) is also known as Perabrodil, Umbradil, Pyelosin, Diodone, and Pyelumbrin.

‡ All Diodrast is identified by a batch number.

(2) Injection of the indicator dye was delayed until just before sacrifice of animals at 1, 3 or 6 hours.

(D) In animals 58–62 the effect of 35 per cent instead of 75 per cent Diodrast was studied as in group B.

(E) The cortices of animals 53–74 were first exposed by removal of the calvarium and bilateral portions of dura; the cortices were placed under continuous observation under the dissecting microscope; then injections of 70 per cent Diodrast and indicator dye were carried out as described above. Animals 69–74 received Diodrast from a batch not used on any other animals in these studies.

(F) Three rabbits (75–77) were sacrified after the usual procedure, but in addition, radioactive diiodofluorescein was injected with the test dye. These brains were examined grossly for staining and were then sectioned sagittally. The radioactivity of each separate half was measured with a Geiger-Mueller tube.

(G) Four patients (brain tumor suspects) were injected with measured amounts (in terms of radioactivity) of radioactive diiodofluorescein and were examined with a shielded Geiger-Mueller counter in the routine manner for localization of brain tumors as described by Moore.[14,15] Twenty-four hours or longer after this examination, unilateral percutaneous carotid angiography was performed with 35 per cent Diodrast. Previous studies have shown that after 24 hours the blood level of diiodofluorescein is negligible, but that some of the radioactive dye is still retained in the liver and gastrointestinal tract.[15] Therefore, following the angiogram, a second counting was done utilizing the same positions and sequence of counting as in the initial counting. In this manner the contribution of the residual radioactivity to each counting position was measured. Then the same dosage in millicuries of radioactive diiodofluorescein was again injected and another counting made in identical manner. The second counting was considered as background for the third and was subtracted from it. The resulting differences were then compared directly with the counts obtained at the first counting.

## RESULTS

(A) The control animals (1–18) revealed no gross staining, but animals that received a very high dosage of fluorescein did show a very faint degree of fluorescence under ultraviolet light. Such high dosages were avoided in the experimental animals. The control animals are summarized in Table 1.

The experimental results for the animals receiving the contrast media are tabulated in Table 2.

(B) The first 10 animals (19–28) studied after the injection of 70 per cent Diodrast revealed no systemic or localized cerebral reaction grossly or pathologically. Unfortunately the batch number of this Diodrast was not recorded. Because Broman and Olsson[3,4] had reported such consistent breakdown of the blood-brain-barrier with 70 per cent Perabrodil (Iodopyracet), a new supply of Diodrast was obtained and the series extended with no other change in the experimental method. Three separate batches of 70 per cent Diodrast were used in these animals. A complete reversal of the previous results was obtained. In every one of these animals (29–46) examination showed a deep staining on the ipsilateral side, and occasionally the homolateral cerebellar hemisphere was also involved. In animal 46, the arterial pressure was exceeded, and in this animal the cerebral and cerebellar hemispheres were bilaterally deeply colored.

TABLE 1

*Control group for dye-substances*

| Animal | Dye-Stuff | Amount | Duration | Result |
|---|---|---|---|---|
| 1–3 | Fluorescein 5% | 2.5 cc. | 20 min. | No staining of brain |
| 4–6 | Fluorescein 5% | 4 cc. | 20 min. | Only slight surface staining without penetration |
| 7–9 | Disulphine blue | 3 cc. | 20 min. | No staining |
| 10–12 | Disulphine blue | 6 cc. | 20 min. | Staining of brain vague |
| 13–15 | Trypan blue (Saturated solution filtered) | 7.5 cc. | 20 min. | No staining of brain tissue |
| 16–18 | Trypan blue (Saturated solution filtered) | 15 cc. | 20 min. | No staining of brain tissue |

With one exception, all of these animals (29–46) had convulsive movements during the injection of Diodrast. The severity of their seizures paralleled the intensity of cerebral staining. The presence of convulsions was invariably accompanied by staining, but in the subsequent studies on

TABLE 2

*Experimental Animals*

| Animal | Diodrast Concentration and Amount | Dye Amount | Injection Time | Interval before Sacrifice | Staining | Results |
|---|---|---|---|---|---|---|
| 19–20 | 70%—20 cc. | TRB | 6 min. | 40 min. | 0 | No comment |
| 21 | 70%—20 cc. | 12 cc. | 5 min. | 1 hour | 0 | No comment |
| 22 | 70%—10 cc. | Disulfine blue 3 cc. | 4 min. | 15 min. | 0 | No comment |
| 23 | 70%—10 cc. | Disulfine blue 3 cc. | 10 min. | 30 min. | 0 | No comment |
| 24 | 70%—15 cc. | Disulfine blue 3 cc. | 10 min. | 45 min. | 0 | No comment |
| 25 | 70%— 6 cc. | Disulfine blue 3 cc. | 2 min. | 30 min. | 0 | No comment |
| 26 | 70%—20 cc | Disulfine blue 3 cc. | 4 min. | 2 hours | 0 | No comment |
| 27 | 70%—20 cc. | Disulfine blue 3 cc. | 4 min. | 3 hours | 0 | No comment |
| 28 | 70%— 7 cc. | Disulfine blue 3 cc. | 3 min. | 15 min. | 0 | No comment |
| 29 | 70%— 7 cc. | Disulfine blue 3 cc. | 3 min. | 10 min. | + | Convulsions |
| 30 | 70%— 5 cc. | Disulfine blue 3 cc. | 3 min. | 15 min. | + | Convulsions |
| 31–40 | 70%— 9 cc. | Fluorescein 2 cc. | 2 min. | 20–45 min. | + | Convulsions |
| 41–42 | 70%— 8 cc. | Fluorescein 2 cc. | 45 sec. | 15 min. | + | No convulsions in 1 |
| 43 | 70%— 5 cc. | Fluorescein 2 cc. | 1 min. | 15 min. | + | Convulsion |
| 44–45 | 70%—10 cc. | Disulfine blue 3 cc. | 3 min. | 7–12 min. | + | Convulsion |
| 46 | 70%—17 cc. | Disulfine blue 3 cc. | 4 min. | 30 min. | Bil. | Convulsion |
| 47–52 | 70%—10 cc. | Fluorescein 2 cc. | 2 min. | 6 hours | 0 | Convulsions |
| 53–55 | 70%—10 cc. | Fluorescein 2 cc. | 2 min. | 3 hours | ? | Convulsions |
| 56–57 | 70%—10 cc. | Fluorescein 2 cc. | 2 min. | 1 hour | + | Convulsions |
| 58–60 | 35%—10–25 cc. | Fluorescein 2 cc. | 3 min. | 20 min. | 0 | No convulsions |
| 61–62 | 35%—20–25 cc. | Fluorescein 2 cc. | 4 min. | 20 min. | + | Convulsion in 1 animal |
| 63–68 | 70%—10 cc. | Fluorescein 2 cc. | 1½ min. | 15 min. | + | Convulsions |
| 69–73 | 70%—10 cc. | Fluorescein 2 cc. | 1½ min. | 15 min. | 0 | No convulsions |
| 74 | 70%—10 cc. | Fluorescein 2 cc. | 2 min. | 15 min. | + | ? Convulsions |

35 per cent Diodrast the reverse was not true. All animals had dyspnea (frequently respiratory failure) and most had an immediate fall in blood pressure associated with bradycardia. These reactions could be reduced by premedication with atropine sulfate.

Grossly, the hemispheres were identical except for the staining with the test dyes. Microscopic sections of representative areas from both hemispheres were made and stained with Mallory's phosphotungstic hematoxylin, and hematoxylin and eosin. No pathological changes were seen. Since the test dyes are very soluble, no trace of them was seen in the microscopic preparations.

(C) Eleven animals (47–57) were sacrificed not immediately, but at 1, 3 or 6 hours to determine the duration of the altered vessel permeability. The staining was still very definite at 1 hour, vague at 3 hours, and absent at 6 hours.

(D) Five animals (58–62) were injected with 35 per cent Diodrast. Staining occurred only with very great amounts (over 30 cc.) of Diodrast.

(E) Interesting observations were made on the cortical vessels of animals (63–74) under the dissecting microscope. In animals 63–68, there was marked dilatation of the cortical vessels, as they filled with Diodrast; this was not discernible with the naked eye. One minute following the completed injection the vessels regained their previous size and remained unaltered throughout the subsequent observation period (10–15 minutes). All these animals had convulsions, and the ipsilateral hemisphere was deeply stained by the test dye.

A new supply of 70 per cent Diodrast with a different batch number was used for animals 69–74. These animals had no convulsions, and exhibited very slight dilatation of the vessels and no dying of the tissue until an excessive amount of Diodrast (30 cc.) was used.

(F) One (76) of the 3 animals (75–77) given the radioactive dye had only a most minor type of convulsion; the other 2 had severe seizures and all 3 showed staining, but it was less marked in animal 76. Also in this animal the counts from the ipsilateral hemisphere were only 17 per cent greater than the opposite, while the other 2 revealed a differential of 51 per cent and 218 per cent (Table 3).

(G) In the 4 patients (Table 4) studied with the radioactive fluorescein method before and after unilateral carotid angiography with 35 per cent Diodrast, there was a significant increase in the counts after angiography in most of the counting areas. As a rule this increased count was bilateral and general over the entire hemisphere. But there were exceptions; in one patient the increased count was only on the side of the angiography, and in another the increases were more evident on the side opposite the angiography.

## DISCUSSION

*Previous Experiments.* Review of the literature reveals few experimental studies in animals on the effects of Diodrast on the cerebral arteries.

TABLE 3

*Animals receiving radioactive dye*

| Animal | Diodrast Concentration and Amount | Dye Amount | Injection Time | Interval before Sacrifice | Counts Recorded % Inc. on Affected Side | Staining | Remarks |
|---|---|---|---|---|---|---|---|
| 75 | 70%—10 cc. | | 1.25 min. | 20 min.× | 51% | + | Convulsions |
| 76 | 70%—10 cc. | Disulphine blue 10% | 1.5 min. | 20 min.× | 17% | + | ? |
| 77 | 70%—15 cc. | Disulphine blue 10% | 2.66 min. | 20 min.× | 218% | + | Convulsions |

TABLE 4

*Patients with pre- and post-angiogram, diiodofluorescein studies*

| Pt. | Diagnosis | Pre-angiogram Dose | Post-angiogram Dose | Hrs. after Angiogram | Increase in Counting Rate | Comment |
|---|---|---|---|---|---|---|
| 1 | Astrocytoma | 1.30 mc. | 1.13 mc. | 5.5 | 0–50% | No lateralization; most differentials greater than 10% |
| 2 | Vascular degenerative | 1.89 mc. | 1.97 mc. | 1.5 | 50–70% | Occasionally greater on side of angiogram |
| 3 | Postradiation degenerative | 0.47 mc. | 0.51 mc. | 5.5 | 7–40% | No lateralization. Occasional differential on contralateral side. |
| 4 | Idiopathic epilepsy | 1.53 mc. | 1.56 mc. | 2.0 | 10–60% | Most differentials 30–60%. |

Gross[11] reported Diodrast injections in 7 dogs, using variable concentrations of the dye. No reactions that were attributed to the dye substance occurred.

Kristiansen and Cammermeyer[12] reported the use of "Perabrodil" in rabbits with no signs of toxicity including histological study of sections taken 11–48 days after injection.

The blood-brain-barrier concept holds that the intracranial vessels have the property of being impermeable to many substances that pass the remaining vessels of the body with ease. These substances include certain toxins, drugs, antibiotics, and such acid dyes as trypan blue and sodium fluorescein. Trypan blue has been the classical dye used to demonstrate alterations in the blood-brain-barrier since Goldmann[10] first described its use. An excellent summary of the knowledge about the blood-brain-barrier has recently appeared in monographic form.[2]

Broman and Olsson[3,4] have made two reports of a study of the effect of Diodrast on the blood-brain-barrier. In their experiments the Diodrast was perfused through the carotid artery of cats and rabbits, and trypan blue was the indicator dye. They concluded that 70 per cent Diodrast was too toxic for use in humans and that 50 per cent and even 35 per cent solutions could not be considered innocuous; if the latter two were used, they believed that repeated injections with long duration of exposure of the vessels to Diodrast should be avoided. In their experiments the force of injection was not controlled. Recently Broman[1] has acknowledged the importance of controlling injection pressures in experimental studies. This is less important clinically since the relative difference between the calibre of the injection needle and the diameter of the vessel is greater.

*Clinical Experience.* Clinically various major reactions to Diodrast angiography have been reported. These have included convulsions[7,17] hemiplegia,[6,7,17] and death,[5,7,8] and were probably on the basis of the reaction of the cerebral vessels and parenchyma to the contrast media. The cases of hemiplegia have, for the most part, been transient, lasting usually for less than 3 hours.[2,6,7] Death in these cases has usually been assumed to be due to the intracranial lesion since in most instances it occurred in very seriously ill patients.[5,7,8,17]

*Present Studies.* The results of the experiments of Broman and Olsson[3] cannot be accepted as a true measure of the noxious effect of Diodrast since the force of injection was not controlled and the vascular damage could well have been due to increased intraluminal pressure. The present studies have confirmed their report that 70 per cent Diodrast is very harmful to the permeability of the cerebral vessels even when the force of injection is controlled. The association of convulsions and respiratory and vasomotor changes with the altered permeability suggests that 70 per cent Diodrast is not innocuous despite the absence of microscopic changes after its injection. A 35 per cent solution of Diodrast was much less harmful. Certainly when the injection times recorded by Broman and Olsson[3] are compared with ours, we must conclude that they greatly exceeded the normal arterial pressure at some point of the injection, because they injected the same or larger amounts of dye in much less time than was possible in these studies without exceeding the normal arterial pressure.

The most significant finding of the present studies is the failure to "break" the blood-brain-barrier with two of the five batches of 70 per cent Diodrast used. It is assumed that these two batches were separate because they were obtained from the manufacturer on separate orders many months apart. Certainly, every animal studied with these two batches failed to show any alteration in the permeability of the cerebral vessels while all others just as consistently revealed very definite alterations. Since there was no difference in the experimental technique, the only possible conclusion is that different batches of the same contrast medium from the same manufacturer vary widely in toxicity. It is suggested that the technique outlined may be used to screen out the more toxic batches.

Observations on the duration of the altered permeability have revealed that it is very transient—less than 3 hours. This correlates very well with the duration of transient hemiplegias reported in clinical Diodrast cerebral angiography.

The use of the dissection microscope has shown that, in the rabbit, Diodrast produces a temporary vasodilatation of the cortical vessels.

That radioactive diiodofluorescein concentrates in very significant amounts in that hemisphere of the rabbits exposed to 70 per cent Diodrast was very convincingly shown. This was not as clearly demonstrated in patients after angiography with 35 per cent Diodrast solution, but these patients did reveal a definite increase in the externally measured radioactivity of the head, although there was no definite laterality to this increase. Indeed, only one patient had a tendency to lateralization on the side of the angiogram while one had just the reversed situation. It must be remembered that the conditions of the animal experiments differed from those in the clinical studies.

1. The rabbits received a comparatively much greater dose of the Diodrast in cubic centimeters of Diodrast per unit weight of the subject.
2. The rabbits received 70 per cent Diodrast, the humans 35 per cent.
3. Each of the rabbits' hemisphere was counted separately with no complicating contributions from the other hemisphere, the bone of the skull, the muscle, the scalp, or the other organs of the body.
4. The human subjects examined after angiography had a constant flow of blood, highly radioactive (in comparison with the brain), through the brain; the rabbits had been drained of most of their blood when sacrificed by cardiac section.

While these considerations give much basis for speculation, no conclusion can be given to explain the absence of definite laterality in the human. Despite this unexplained observation, it can still be stated that clinical carotid angiography results in an increase in the measurable amount of radioactivity when studied with the radioactive diiodofluorescein method.[15,16] The best explanation of this is an increased vascular permeability such as has been established in the experimental animal, and the same phenomena in severe degree could account for the convulsions and transient hemiplegias seen clinically. It could account for deaths in patients, especially those tumor victims who have edema with an already established alteration in permeability.

## SUMMARY AND CONCLUSIONS

An experimental study in animals has been carried out to determine the effect of Diodrast carotid angiography on the cerebral vascular permeability (the so-called blood-brain-barrier) as determined by the dyes, trypan blue, disulphine blue, sodium fluorescein, and radioactive diiodofluorescein.

It has been shown that 70 per cent Diodrast usually destroys the blood-brain-barrier in the rabbit accompanied by such phenomena as convulsions, and marked depression of respiration, blood pressure and pulse. A

35 per cent solution of Diodrast has been shown to be much less toxic in this respect.

The failures of 70 per cent Diodrast to produce this result consistently in all animals but only with certain batches of the medium leads to the conclusion that different batches of Diodrast vary greatly in their toxicity to the cerebral vessels. Such a procedure as used in these animal experiments might be used to identify and eliminate the more toxic batches of Diodrast.

This damage persists not over 3 hours. This correlates well with the duration of reported instances of transient hemiplegias in clinical Diodrast angiography.

Clinical studies using the radioactive diiodofluorescein technique before and after angiography have produced the conclusion that even 35 per cent Diodrast produces some alteration of the vascular permeability in the human brain. This could be the cause of the major intracerebral complications produced by angiography.

## REFERENCES


1. Broman, T. Personal communication.
2. Broman, T. The permeability of the cerebrospinal vessels in normal and pathological conditions. *Copenhagen: E. Munksgaard*, 1949, 92 pp.
3. Broman, T., and Olsson, O. The tolerance of cerebral blood-vessels to a contrast medium of the Diodrast group. An experimental study of the effect on the blood-brain-barrier. *Acta radiol., Stockh.*, 1948, *30:* 326–342.
4. Broman, T., and Olsson, O. Experimental study of contrast media for cerebral angiography with reference to possible injurious effects on the cerebral blood vessels. *Acta radiol., Stockh.*, 1949, *31:* 321–334.
5. Bull, J. W. D. Cerebral angiography. *Postgrad. med. J.*, 1950, *26:* 157–165.
6. Chusid, J. G., Robinson, F., and Margules-Lavergne, M. P. Transient hemiplegia associated with cerebral angiography (diodrast). *J. Neurosurg.*, 1949, *6:* 466–474.
7. Dunsmore, R., Scoville, W. B., and Whitcomb, B. B. Complications of angiography. *J. Neurosurg.*, 1951, *8:* 110–118.
8. Engeset, A. Cerebral angiography with perabrodil (carotis angiography). *Acta radiol., Stockh.*, 1944, suppl. 56, 207 pp.
9. French, L. A., and Blake, P. S. Cerebral angiography. *Minn. Med.*, 1949, *32:* 589–595.
10. Goldmann, E. E. Vitalfärbung am Zentralnervensystem. Beitrag zur Physio-Pathologie des Plexus chorioideus und der Hirnhäute. *Berlin: G. Reimer*, 1913, 60 pp.
11. Gross, S. W. Cerebral arteriography in the dog and in man with a rapidly excreted organic iodide. *Proc. Soc. exp. Biol., N. Y.*, 1939, *42:* 258–259.
12. Kristiansen, K., and Cammermeyer, J. An experimental investigation on the effect of arteriography with Perabrodil on the brain. *Acta radiol., Stockh.*, 1942, *23:* 113–130.
13. Moniz, E. L'encéphalographie artérielle, son importance dans la localisation des tumeurs cérébrales. *Rev. neurol.*, 1927, *2:* 72–89.
14. Moore, G. E. Use of radioactive diiodofluorescein in the diagnosis and localization of brain tumors. *Science*, 1948, *107:* 569–571.
15. Moore, G. E., Kohl, D. A., Marvin, J. F., Wang, J. C., and Caudill, C. M. Biophysical studies of methods utilizing fluorescein and its derivatives to diagnose brain tumors. *Radiology*, 1950, *55:* 344–362.
16. Moore, G. E., Peyton, W. T., French, L. A., and Walker, W. W. The clinical use of fluorescein in neurosurgery. The localization of brain tumors. *J. Neurosurg.*, 1948, *5:* 392–398.
17. Torkildsen, A. Carotid angiography with special reference to the diagnosis of cerebral gliomas. *Acta psychiat., Kbh.*, 1949, suppl. 55, 168 pp.

# THE ROLE OF SMALL ANGIOMATOUS MALFORMATIONS IN THE PRODUCTION OF INTRACEREBRAL HEMATOMAS

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THE etiologic background of intracerebral hemorrhage falls readily into certain well defined categories, which include hypertensive-arteriosclerotic apoplexy, aneurysms of the berry or medial-defect type, angiomatous malformations, trauma, blood dyscrasias, and neoplasms. But in any series of cerebral hemorrhages one invariably encounters a group of unknown etiology.[1,3,4,14] To this group certain features are common, namely:

1) occurrence in a relatively young age group;
2) absence of any known predisposing factors, except an occasional history of trauma;
3) suddenness of onset, usually with headache;
4) delayed loss of consciousness;
5) location of the bleeding usually within the white matter;
6) absence of a demonstrable anatomic cause for the bleeding.

Several excellent reviews[3,4,9] have presented detailed discussions of all of the etiologic factors postulated for these hemorrhages. The various concepts dealing with the pathogenesis of apoplexy have been considered, but the age-distribution and the absence of significant arteriosclerosis in this group argue convincingly against vascular degenerative disease being the common background for these lesions. The relationship to trauma is inconstant, remote, and often equivocal. Infectious and toxic agents have been excluded in carefully studied cases. Most reports ascribe no definite causative factor. It is of historical interest that Hawthorne[8] in 1922 was impressed by their occurrence in apparently healthy children and adolescents.

The relationship of large vascular anomalies to cerebral hemorrhage is well known, an incidence of 50 per cent being reported by Olivecrona and Riives,[13] and a frequency of 41 per cent being found in a review of Dandy[5] limited to arteriovenous aneurysms. But the role of small angiomatous formations in the production of intracranial hemorrhage is less well known. Three examples of bleeding from small macroscopic lesions have been reported from the clinic of Olivecrona.[2,12,13] Hawkins and Rewell[7] described 2 cases, and Bagley[1] another, of fatal hemorrhage related to cavernous

angiomas that were demonstrable only at a microscopic level. Kidd and Cumings[10] discussed a family presenting a history of 10 deaths in two generations from cerebrovascular accidents occurring in youth. Two of these subjects were autopsied, one showing a hemorrhage associated with an angioma revealed in sections, the other presenting old and recent hematomas without a demonstrable background.

A survey[16] of the problem of intracranial hemorrhage currently being undertaken at Duke Hospital has indicated (1) that a considerable proportion of hemorrhages are without demonstrable cause and (2) that small angiomatous malformations may play a more significant role than usually recognized. Over a 20-year period 14 hematomas of unknown etiology and 9 instances of hemorrhage from angiomatous malformations have been found, compared with 55 cases of hypertensive-arteriosclerotic apoplexy and 29 hematomas resulting from ruptured berry aneurysms.

Six fatal hematomas related to vascular malformations were studied at autopsy. Four were found to have been produced by rupture of small lesions. The minute size of one of these, the difficulty in demonstrating the second, and the deep-seated situation of the others point to their possible role in the production of so-called spontaneous intracranial hemorrhage. The incidental finding of two other examples of cerebral vascular lesions susceptible of being obliterated by related hemorrhage again emphasizes this possibility. These cases are being reported in this aspect.

## CASE REPORTS

Two examples of massive fatal intracranial hemorrhage arose from vascular malformations that were not evident grossly. In Case 1, a tiny arteriovenous angioma was demonstrated only after multiple sections of the wall of a subcortical hematoma had been studied. In Case 2, a pontine lesion was so nearly destroyed by the related hemorrhage that its classification as a cavernous angioma is difficult. With neither of these lesions was the afferent or efferent circulation demonstrable.

*Case 1.* J. B., a 12-year-old white male, had sudden onset of a headache during a contest with his playmates "to see who could blow a harmonica the loudest." The child became progressively less responsive and vomited frequently.

On admission 12 hours later temperature was 37°C., pulse 96, respirations 22, and B. P. 118/66. The principal neurological findings included semicoma, left hyperreflexia, and a left Babinski sign. The CSF was clear and free of RBC; the pressure was not recorded. Bilateral pyramidal signs developed and death occurred on the 4th day of illness.

*Autopsy* findings were irrelevant except for the cerebral changes. A massive subcortical hematoma, 6×4×4 cm., was found in the left parietal lobe, confined to the white matter (Fig. 1A). No subarachnoid bleeding was present. No gross source of the bleeding was demonstrated, and study of the lesion with a dissecting microscope gave no further indication of the background of the hematoma. The parenchyma in the wall of the hemorrhage was unaltered except for congestion and multiple small hemorrhages.

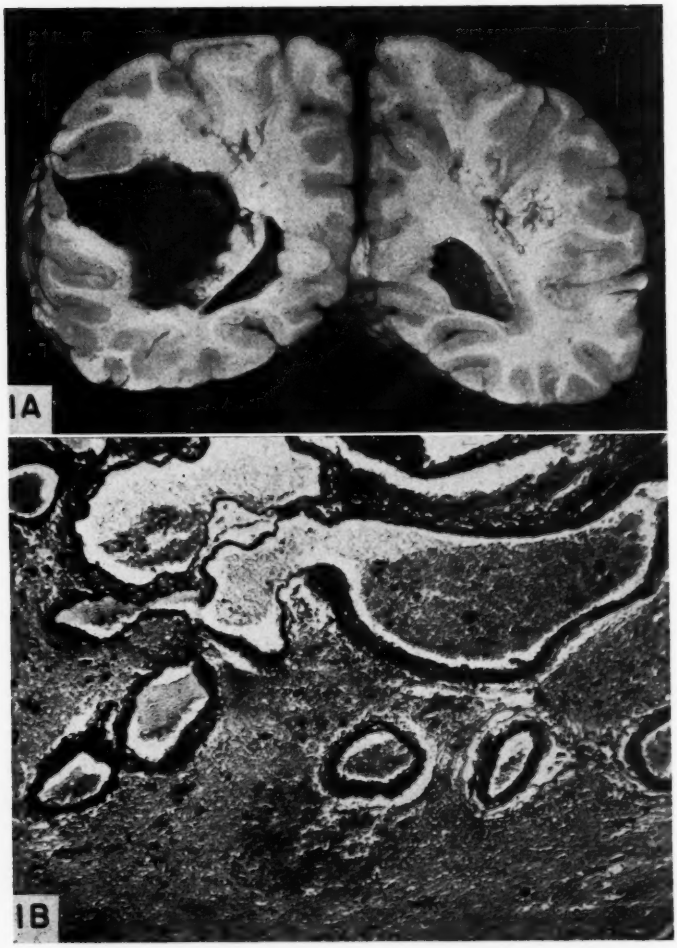


FIG. 1. *Case 1.* (A) Coronal section of brain showing large hematoma in left parietal lobe. No gross vascular malformation was demonstrable. (B) Complexly branching vessels of venous structure showing abrupt thinning of walls. Masson, ×69.

Of many blocks selected from the hematoma wall, one revealed a tiny arteriovenous angioma contained largely within the meninges of a single sulcus and 3 to 5 mm. of parenchyma bordering the hemorrhage. The most superficial vessels were tortuous arteries, altered by fibrous intimal plaques and zones of thinning and fibrosis of the muscularis. Deeper in the sulcus sinuous and straight vessels of venous character entered the brain parenchyma, branched complexly and were dispersed. Abrupt thinning occurred in the walls of some of these vessels, the media giving way suddenly to a thin endothelial lining (Fig. 1B). The parenchyma related to the vessels presented a few foci of gliosis; there was no evidence of an older hemorrhage.

*Case 2.* M. R. C., a 2½-year-old white female, fell from a swing 40 hours prior to admission and struck the left frontotemporal region. There was no loss of consciousness. Four hours later the child began complaining of generalized headache; after 12 hours the headache became more severe and cerebration became progressively slower until stupor supervened. On the morning of admission left ptosis and left hemiparesis were observed. Bloody CSF had been found by the referring physician.

On admission temperature was 37.8°C., pulse 124, respirations 24, and B. P. 90/66. X-rays of the skull were negative. The principal neurologic findings included stupor, a slightly stiff neck, left ptosis and dilated pupils which reacted to light. There was paresis of all extraocular muscles. Left hemiparesis and hyperreflexia were present. Subsequently, there developed a right peripheral 7th nerve paralysis, and respiratory embarrassment, and the patient expired 3 days after onset.

*Autopsy* revealed no disease outside of the central nervous system. The caudal portion of the pons was greatly expanded and virtually destroyed by a circumscribed hematoma, 3×2×2 cm. (Fig. 2A). A few smaller hemorrhages bordered the larger lesion, but no gross traces of an older hemorrhage were observed. Slight subarachnoid bleeding was present. There was no gross evidence of an abnormal vascular pattern in the parenchyma or meninges related to the lesion.

Sections demonstrated the lesion from which the bleeding had its origin, virtually destroyed by the hemorrhage. At some borders of the hematoma there were small numbers of collapsed cavernous vessels with thin walls, consisting of a single layer of endothelium and basement membrane, or a rim of hyaline connective tissue (Fig. 2B). The lesion was confined entirely to the parenchyma. Older small hemorrhages were evident at the periphery of the lesion, where gliosis, hemosiderin pigment within histiocytes, and basophilic depositions upon the basement membrane of telangiectatic vessels were observed.

Two examples of massive fatal cerebral hemorrhage arose from deep-seated small venous malformations. In neither of these was the afferent circulation discovered. In one the venous drainage to an internal cerebral vein was demonstrated. These cases are reported below.

*Case 3.* S. P., a 7-year-old white female, fell from a chair while in school and remained stuporous until admission 24 hours later. She complained of right frontal headache and vomited several times. A left hemiparesis was noted soon after onset. The patient had struck her head against the door 2 days prior to her present illness with no loss of consciousness or immediate sequellae. Two to 3 years previously she had experienced an episode of severe right-sided headache, nausea and vomiting lasting 2 to 3 days.

On admission temperature was 37.4°C., pulse 100, respirations 22, and B. P. 110/80. The patient was semicomatose. Her neck was supple. A left hemiparesis was present, most marked in the arm. The CSF was clear, and contained no RBC; the pressure was 170 mm. of $H_2O$. Deep coma supervened, decerebrate attacks developed, and death occurred on the 4th day of illness.

*Autopsy* revealed no pertinent changes outside the central nervous system. In the right cerebral hemisphere a massive hematoma, 12×6×4 cm., occupied most of the centrum semiovale, extending from a retrolenticular level nearly to the frontal pole (Fig. 3A). The hemorrhage was recent, and was sharply delimited, especially at the external margin of the putamen, where it had cleaved the parenchyma, rather than destroying it in its dissection. No intraventricular or subarachnoid bleeding had

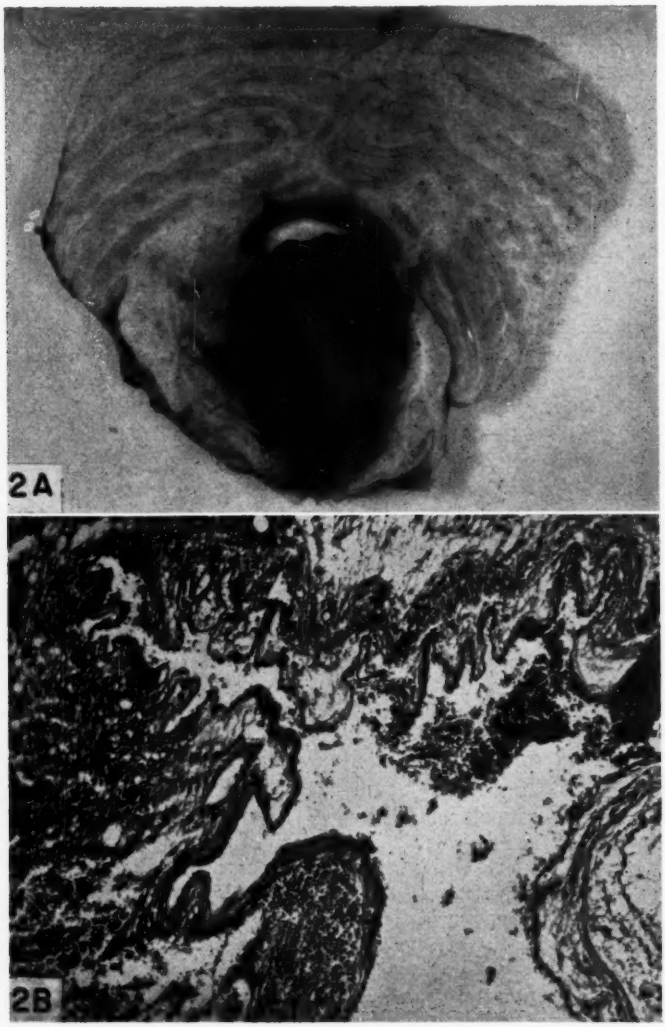


FIG. 2. *Case 2.* (A) Transverse section of pons showing large hematoma. No gross vascular malformation was observed. (B) Wavy, collapsed, thin wall of a cavernous vessel at margin of hemorrhage. Hematoxylin-eosin, ×107.

occurred. The source of the hemorrhage was a small venous angioma at the inferomedial margin of the hematoma (Fig. 3A). This lesion, which consisted of small, widely dispersed vessels, occupied a zone of white matter approximately 1.5 cm. in each dimension. These vessels, the largest of which measured 1 mm. in diameter,

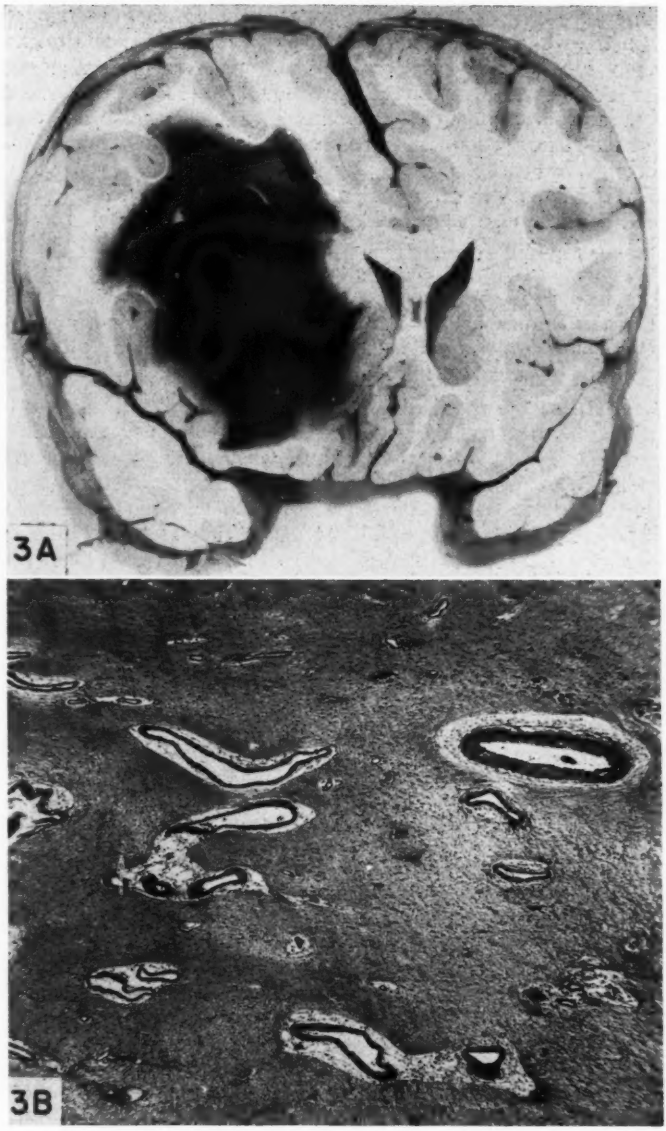


FIG. 3. *Case 3.* (A) Coronal section of brain showing massive hematoma in right centrum semiovale. At the inferomedial border the venous angioma is seen, and below this the cystic remnant of an older hemorrhage. (B) Varied-sized vessels of venous structure within white matter. Hematoxylin-eosin, ×31.

diminished progressively in size and number at the margins of the lesion, being lost anteriorly in the white matter and posteriorly within the caudate nucleus. There were no abnormalities of arterial or venous pattern in the related parenchyma or meninges to indicate the afferent or efferent circulation of the lesion. At the anterior margin of the malformation a cleft-shaped zone of encephalomalacia in the medullary core of the right gyrus rectus, bordered by brown-stained parenchyma, gave evidence of an older hemorrhage.

The microscopic pattern of the lesion presented widely scattered vessels within an unaltered parenchyma. The vessels varied from muscular veins to thin-walled venules (Fig. 3B); no arterial structures were observed. Irregular hyaline plaques produced advanced narrowing of some lumina. The wall of the recent hematoma contained many necrotic, thrombosed vessels, and ring- and ball-shaped hemorrhages. The older hemorrhage, remote from the recent bleeding, presented areas of cyst formation, fibrous gliosis, and hemosiderin pigmentation both within histiocytes and upon the cell bodies of large astrocytes.

*Case 4.* V. R., a 29-year-old white female, had onset of right retro-orbital pain 16 hours prior to admission. This progressed in severity and 2 hours later a left hemiparesis was noted. Forty-five minutes thereafter the patient became comatose.

On admission, temperature was 37.4°C., pulse 52, respirations 16, and B. P. 100/70. The principal neurological findings included semicoma, left hemiparesis, and slight nuchal rigidity. The right pupil became fixed to light. The state of consciousness remained unchanged. Sudden respiratory death occurred 44 hours after onset.

*Autopsy* demonstrated the absence of evidence of kidney disease, hypertension, or significant atherosclerosis. In the left cerebral hemisphere a hematoma, 4 cm. in each dimension, occupied the frontal lobe anterior to the basal ganglia (Fig. 4A). It approached the anterior tip of the lateral ventricle, but the ventricles and subarachnoid space were free of gross bleeding. At the ragged medial margin of the hemorrhage a venous angioma was observed (Fig. 4A). This consisted of a network of small, thick-walled vessels, distributed sparsely within the otherwise normal parenchyma. The lesion was limited to the frontal portion of the lenticular nucleus, and the adjacent internal capsule and corona radiata. The caliber of the vessels measured 1 mm. or less. Presenting upon the lateral wall of the left lateral ventricle a dilated tortuous venous channel, 3 mm. in diameter, passed into a dilated internal cerebral vein, then into the great cerebral vein. Through these veins retrograde injection could be freely made into the vascular malformation and into the cavity of the hemorrhage. There were no abnormalities in the pattern of the related arterial circulation.

Sections of the lesion showed diffusely scattered vessels, with walls varying from thin endothelial linings to thick fibrous and muscular coats, but most were of venous composition (Fig. 4B). Mural plaques were prominent, ranging from fibrous focal thickening to massive collagenous proliferation that produced near occlusion, especially of some of the largest vessels. A perivascular astrocytic proliferation was prominent but no evidence of older hemorrhage about any of the vessels was observed.

Two small vascular lesions, incidental findings which had not given rise to gross hemorrhages, are presented because their small size illustrates the difficulty of finding the source of any major hemorrhage occurring from them. One of these certainly would have been completely destroyed by

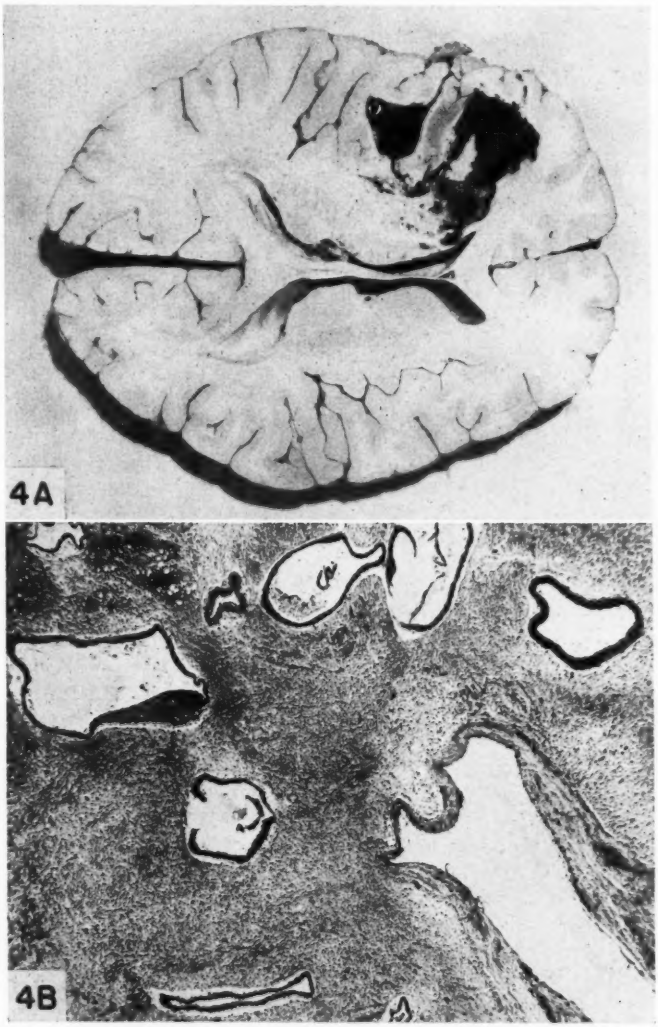


FIG. 4. *Case 4.* (A) Horizontal section of brain showing large hematoma in left frontal and parietal lobes. At the medial margin the venous angioma and an enlarged internal cerebral vein are seen. (B) Thick-walled irregular vessels of venous structure within white matter. Hematoxylin-eosin, ×31.

hemorrhage of any consequence. The description of these lesions follows.

*Case 5.* M. S. This lesion was a small vascular malformation classified as a telangiectasis. It was an arc-shaped lesion, 2 mm. in thickness and about 2 cm. in its coronal and anteroposterior diameter (Fig. 5A), found in the brain of a 37-year-old colored female. The lesion paralleled the cortex in the upper margin of the left su-

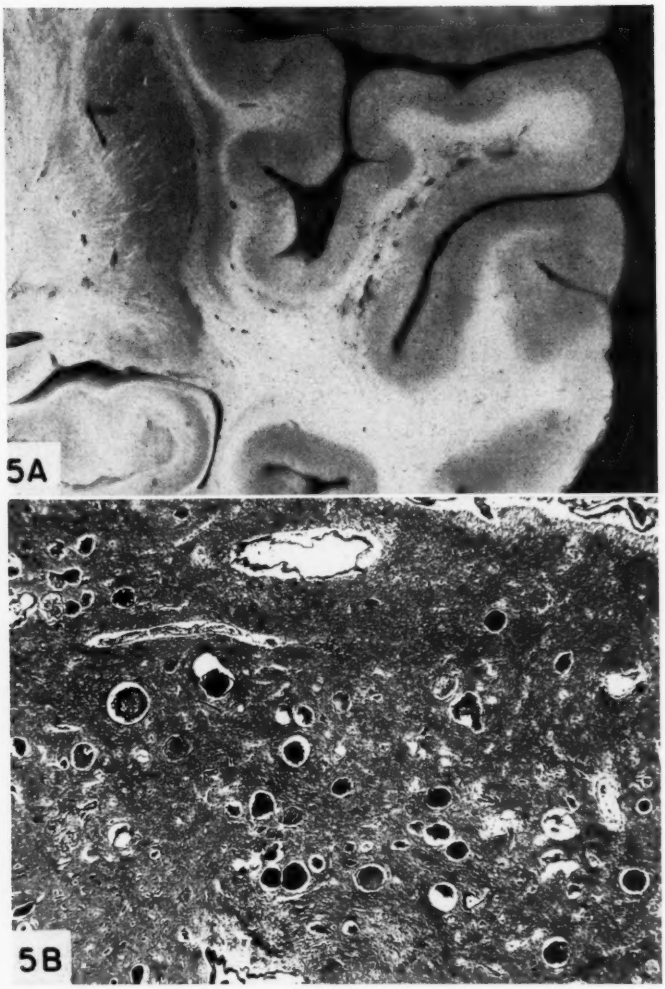


FIG. 5. *Case 5.* (A) Inconspicuous group of small vessels within medullary lamina of superior temporal gyrus. (B) Telangiectatic thin-walled vessels composing the lesion. Hematoxylin-eosin, ×32.

perior temporal gyrus, and had the appearance of a zone of dilated congested vessels, pinpoint to 1 mm. in size, distributed within the otherwise normal white matter. The margins were vague and no feeding or draining vessels were demonstrable.

Sections at coronal levels through the lesion showed it to consist predominantly of dilated vessels which presented regular round cross-sections, appearing only infrequently in the longitudinal plane (Fig. 5B). Their coats were thin, most being composed solely of an endothelial lining. In a few, collagenous fibrous tissue was added to the walls. The vessels were spaced widely in the white matter and their

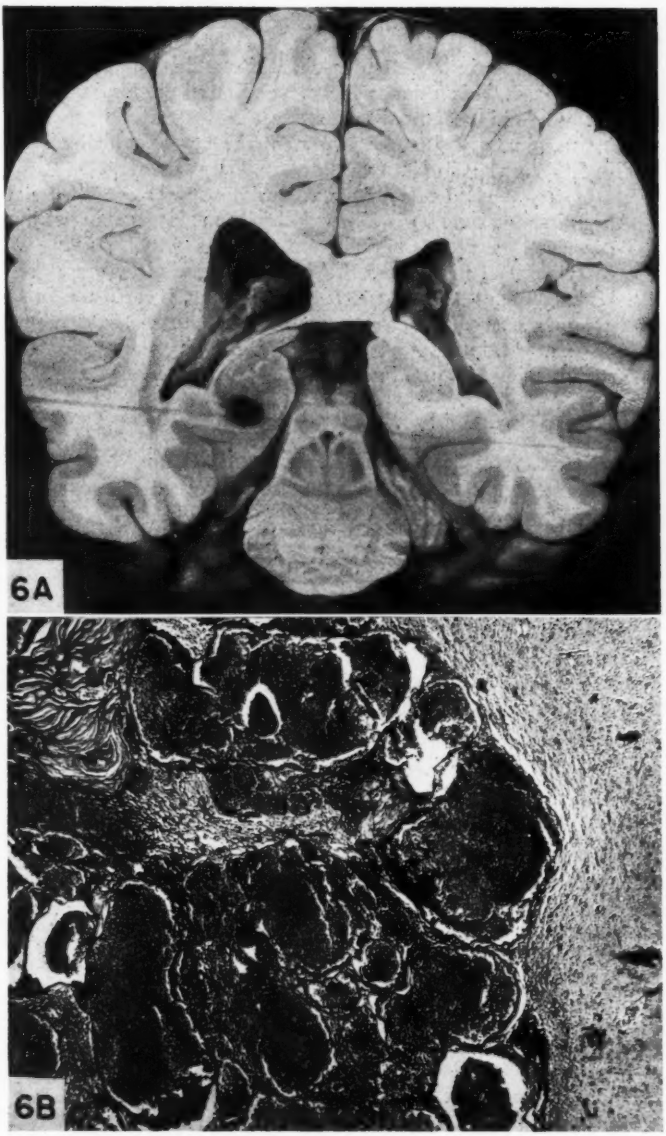


FIG. 6. *Case 6.* (A) Coronal section of brain showing small cavernous angioma adjacent to hippocampus. (B) Cavernous vascular spaces with collagenous septae. Masson, ×37.

numbers diminished rather gradually at the margin of the lesion. No old hemorrhage was observed in the parenchyma and only a slight gliosis was observed.

*Case 6.* J. C. In the brain of a 31-year-old white male, a single small cavernous angioma was discovered. This lesion, which was situated predominantly in the medullary core of the left hippocampal gyrus, measured 8 mm. in greatest diameter and was sharply marginated (Fig. 6A). It presented no gross evidence of past bleeding. No abnormalities in the circulation related to it were evident.

In sections, closely packed blood-filled cavernous spaces constituted the lesion (Fig. 6B). Many of the vessels lay wall to wall without intervening stroma or parenchyma. The walls of the vessels varied from a thin endothelial lining to a fibrous wall a few cell layers thick; in others the vessels were obliterated or replaced by laminae of hyalinized connective tissue. Intervening tissue consisted in some areas of a dense collagenous stroma. Traces of an old small hemorrhage were indicated by hemosiderin pigment within macrophages, and encrusting the cytoplasm of astrocytes and microglia which had proliferated at the borders of the lesion.

## DISCUSSION

Except for the demonstration of the etiologic factor, these 4 hematomas bear a close resemblance to the spontaneous cerebral hemorrhages of unknown etiology. Their clinical aspects, and the type and location of hemorrhage differ in no significant way from 10 cases of intracerebral hematoma of undetermined origin diagnosed surgically, and 4 cases studied at autopsy at Duke Hospital. It is not possible to exclude a vascular malformation as an etiologic factor in those cases studied solely under operative conditions. Nor would angiography be likely to demonstrate minute lesions. Hawkins and Rewell[7] have suggested that a careful search for angiomatous formations be made in the walls of unexplained cerebral hemorrhages occurring in young people. Furthermore, the possibility of destruction or masking of the causative lesion by the hemorrhage has to be considered in cases studied at autopsy. The variety[11] of cerebral vascular malformations and their embryologic background[6,15] have been well documented. It is reasonable to regard all such lesions as potential sources of bleeding.

The delayed loss of consciousness common to hemorrhages of unknown etiology as well as to those related to vascular malformations has been explained on the basis of slow venous bleeding.[4] But the location of these hematomas may be of more significance in this respect than their rate of development.

## SUMMARY

Four cases of intracranial hematomas arising from rupture of small angiomatous malformations are reported, along with 2 other lesions that did not bleed. The clinical and pathological features of these hemorrhages are described. The relationship of minute lesions of this nature to spontaneous cerebral hemorrhage of unknown etiology is suggested.

## REFERENCES


1. Bagley, C., Jr. Spontaneous cerebral hemorrhage. Discussion of four types, with surgical considerations. *Arch. Neurol. Psychiat., Chicago*, 1932, *27:* 1133–1174.
2. Bergstrand, H., Olivecrona, H., and Tönnis, W. Gefässmissbildungen und Gefässgeschwülste des Gehirns. *Leipzig: G. Thieme*, 1936, 181 pp.
3. Buckley, P. J., and McKinney, J. M. Hematoma of the brain. *New Engl. J. Med.*, 1941, *224:* 716–722.
4. Craig, W. McK., and Adson, A. W. Spontaneous intracerebral hemorrhage. Etiology and surgical treatment, with a report of nine cases. *Arch. Neurol. Psychiat., Chicago*, 1936, *35:* 701–714.
5. Dandy, W. E. Arteriovenous aneurysm of the brain. *Arch. Surg., Chicago*, 1928, *17:* 190–243.
6. Dandy, W. E. Intracranial arterial aneurysms. *Ithaca, N. Y.: Comstock Publishing Co., Inc.*, 1944, viii, 147 pp. (see pp. 67–90).
7. Hawkins, C. F., and Rewell, R. E. Unheralded, fatal haemorrhages in haemangiomata of the brain. *Guy's Hosp. Rep.*, 1946, *95:* 88–91.
8. Hawthorne, C. O. Cerebral and cerebellar haemorrhages in apparently healthy adolescents and children. *Practitioner*, 1922, *109:* 425–435.
9. Jewesbury, E. C. O. Atypical intracerebral haemorrhage. With special reference to cerebral haematoma. *Brain*, 1947, *70:* 274–303.
10. Kidd, H. A., and Cumings, J. N. Cerebral angiomata in an Icelandic family. *Lancet*, 1947, *1:* 747–748.
11. Noran, H. H. Intracranial vascular tumors and malformations. *Arch. Path.*, 1945, *39:* 393–416.
12. Olivecrona, H. Die chirurgische Behandlung der Gehirntumoren. Eine klinische Studie. *Berlin: J. Springer*, 1927, v, 344 pp.
13. Olivecrona, H., and Riives, J. Arteriovenous aneurysms of the brain. Their diagnosis and treatment. *Arch. Neurol. Psychiat., Chicago*, 1948, *59:* 567–602.
14. Pilcher, C. Subcortical hematoma. Surgical treatment, with report of eight cases. *Arch. Neurol. Psychiat., Chicago*, 1941, *46:* 416–430.
15. Streeter, G. L. The developmental alterations in the vascular system of the brain of the human embryo. *Contr. Embryol. Carneg. Instn.*, 1918, *8:* 5–38.
16. Unpublished data.

# SPONTANEOUS SUBARACHNOID HEMORRHAGE IN INTRADURAL TUMORS OF THE LUMBAR SAC

## A CLINICAL SYNDROME*

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THIS is a neurosurgical postulate in which there is an abrupt onset of intractable sciatica, a concomitant violent headache and the presence of a liberal amount of fresh blood in the spinal fluid. The total experience on which this study is based is perhaps insufficient for finality. The clinical parallelism in these cases, however, is so striking as to suggest that with a few additional contributions one may confirm the clinical characterization of certain tumors within the dura of the lumbar limits of the spinal canal. The diagnosis of these tumors is completely dependent on contrast myelographic studies of this spinal area. Unless these investigations are inaugurated early, intermittent attacks of radicular distress and cephalalgia can be expected. With present-day attention centered on the "ruptured intervertebral disk" in accounting for lumbago-sciatica handicaps, and the enthusiasm for cerebral angiography in spontaneous subarachnoid hemorrhage, it seems apropos that attention be given this possible syndrome for certain lumbar intradural tumors.

The first case of meningeal hemorrhage caused by a tumor of the cauda equina was reported by André-Thomas *et al.*[2] in 1930. The only other case in the literature was chronicled by Abbott[1] in 1939. It is of passing historical interest, as pointed out by André-Thomas, that Vigneras was in error in his interpretation that "the existence of a yellow fluid on spinal puncture" in 3 of his cases indicated meningeal hemorrhage caused by medullary tumors of the spinal cord. André-Thomas likewise directed similar criticism to Elsberg's report of bleeding tendencies in spinal cord tumors, for Elsberg also thought the xanthochromic spinal fluid was of hemorrhagic origin. So it stands that André-Thomas recorded the first experience of a true recurrent spinal hemorrhage associated with a verified tumor of the cauda equina. The fluid withdrawn in his case was "the color of port-wine . . . withdrawn easily and abundantly . . . when centrifuged the fluid remained colored showing an extensive hemolysis." Cisternal puncture was performed on André-Thomas' patient on the day following a lumbar puncture, and the "cerebrospinal fluid withdrawn was slightly colored but infinitely less bloody than that from the subarachnoid lumbar spaces." Abbott's case

* Read at meeting of Harvey Cushing Society, Hollywood, Florida, April 26, 1951.

represents the extreme frequency with which the symptomatology of such a spinal cord tumor may recur. His patient bled spontaneously on more than 25 occasions. His experiences further illustrate the practical clinical considerations that may be the more evident explanations for these patients' complaints. The primary objective neurologic evidence is likely to be directed to the cerebrum as the site of origin of the spontaneous bleeding.

## CASE REPORTS

There are 5 cases on which this study is based. Three of these are from the author's records. Four of the patients were operated upon by other neurosurgeons.

*Case 1.* Male, aged 33. Reported by André-Thomas, *et al.*[2] in October 1930.

*1st Attack*, April 1923. Severe pain, acute in onset, more severe at night; included "the whole pelvis and thighs." Necessitated several injections of morphia. Patient had had some pain in sacral region and down the posterior thighs since 1918.

*2nd Attack*, March 1927. "Had to be hospitalized twice for three weeks for pain," of the same character and in the same areas of the attack of 1923. Improved spontaneously and "on dismissal returned to his job."

*3rd Attack*, April 1929. This necessitated hospitalization. Again severe "pain in the sacrum, perineal pain radiating into the thighs and up to the shoulders." Recovery was after a short interval and he returned to work. "Some sphincter dysfunction persisted. Permanent stiffness of his spine."

*4th Attack*, April 1930. "Sacro-lumbar pains radiating to the lower limbs." For this attack he was hospitalized and on May 2, 1930 there were motor, sensory, reflex and sphincter disturbances adequate to suspect a lumbar or sacral neoplasm. Lumbar punctures (May 2, 6, 10) showed "still quite bloody cerebrospinal fluid." Pressure and manometrics were not reported.

*Myelography*, May 12, 1930. Lipiodol. Obstruction "at upper edge of the second lumbar vertebra."

*Laminectomy* by Dr. de Martel, May 24, 1930. Intradural tumor "somewhat to the right of the midline, completely extracted from the lumbar 1–2 level."

*Histology.* Neuroglioma.

*Results.* "Incomplete paralysis of extensors of the right foot (improving) and diminution of knee reflex."

*Comment.* It is to be noted in Case 1 that André-Thomas recorded the positive statement that on the day of his examination of the patient "he does not complain of headaches." He did state, however, that his patient suffered radicular irritations remote from the site of the spinal root compression by the tumor. With bloody spinal fluid obtained from the cisterna magna it is quite likely that his patient had had adequate meningeal irritation to produce a cephalalgia of some degree, if not that particular day, at least in previous attacks. The other 4 patients' records indicate headaches as dominant complaints.

In Woodhall's[5] patient (Case 4 of this report), headache "developed a week later than the appearance of severe pain in both legs," and was accompanied by nausea and vomiting. This patient had had headaches as a

dominant symptom in the first episode of spinal bleeding 4 years previously. He recalled that on his first experience he had had "a double vision with that attack of violent sciatica" and stated the diplopia developed with a severe headache. This supposition of the presence of increased intracranial pressure with the first attack was enhanced by the parents' description of "the development of cross-eyedness." It is further noted from the author's records of this case that "on the three occasions" when the patient's attending physician withdrew "bloody spinal fluid" on lumbar punctures the headaches and pains in the child's legs "were definitely relieved." The strabismus disappeared after the third spinal puncture. When this patient was seen in his second attack the headaches and projectile vomiting were as distressing symptoms as his spinal rigidities and spontaneous radicular contractures of the lower extremities.

In Abbott's[1] patient (Case 2 of this report), as well as in Cases 3 and 5, headache was as outstanding a symptom as the lumbar spinal root complaints. It would appear from Woodhall's records in Case 4, as well as in André-Thomas' in Case 1, that there comes a time in the expansion of these cauda equina tumors when continued spinal nerve root compression dominates the clinical picture. The symptoms produced by the spontaneous hemorrhage may then be subjectively minimized. But it is hoped that alertness to this possible syndrome of cauda equina tumors may result in earlier diagnosis and treatment before the development of objective neurological symptoms.

*Case 2.* Male, aged 16. Reported by Dr. Kenneth H. Abbott[1] in September 1939.

*1st Attack*, June 4, 1937. Patient attempted a high jump. Sudden acute lumbago and a blinding headache. Examination indicative of meningeal irritation only. Positive Kernig and Brudzinski. Spinal fluid: pressure over 300 mm. water; very bloody. Rapid disappearance of symptoms.

*2nd Attack*, September 1937. From then until November 1938 some "25 more attacks of acute low back pain and acute headaches." During 3 of these attacks spinal puncture yielded bloody fluid and the supernatent fluid was xanthochromic. No clinical or manometric evidence of spinal cord or low spinal nerve root compression.

*25th Attack.* Spontaneous appearance of sciatica and severe headaches. Spinal fluid bloody. No evidence of spinal canal block. Continued bloody fluid in a series of punctures over ensuing 3 weeks.

*Pneumoencephalography*, Dec. 12, 1938. No evidence of tumor. Mild ventricular enlargement. Myelography refused by parents. Symptoms became persistent.

*Myelography*, Jan. 19, 1939. Obstruction at D12 level.

*Laminectomy* by Dr. R. B. Raney, Jan. 21, 1939. Encapsulated tumor, enveloped by nerves of cauda equina from the tip of the conus medullaris.

*Histology.* Ependymoma.

*Results.* Shock following surgery. Postoperative death. Autopsy: No cerebral vascular anomalies. Mild hydrocephalus, cause undetermined.

*Comment.* The histology of these growths that are prone to initiate periodic spinal hemorrhage is of interest. In Cases 2, 4 and 5 the tumors were typical ependymomas. The chronicity of this type of glioma[3,4] is well estab-

lished and hence the long histories of recurrent symptoms are understandable. The hemorrhagic tendencies of tumors of the cauda equina have heretofore escaped the cognizance this condition demands. The hypertrophy of the pial vessels associated with these tumors is partially attributed to a mechanical obstruction. With violent physical efforts, because of the thin walls of these vessels, a rupture is conceivable. Spontaneous hemorrhage without physical influences, however, escapes logical interpretation. In André-Thomas' case the histologic reproduction is printed on a poor grade of paper but the depiction could well be that of an ependymoma. His histological diagnosis, even though the tumor "was traversed by a spinal nerve root," was "vascular neuroglioma." In view of the fact that this was reported as late as 1930, it is unlikely that the tumor was a neurofibroma. Thus it is possible that 4 of the 5 tumors associated with proven episodes of repeated spontaneous spinal bleeding may be of the same cellular type. Case 3 is the only instance of the tumor being definitely not of ependymal origin. This lesion was reported by a most able pathologist as a "neurofibroma of unusual vascularity." So in this proposed syndrome, one might, with added experiences, not only learn that a spinal cord tumor is the explanation for the spontaneous appearance of headaches and sciatic pain, but might even venture to predict the histologic character of the growth with a fair degree of accuracy.

*Case 3.* #37-358. Male, aged 37. First seen July 24, 1937. Postoperative case of spinal cord tumor. No complaints. Referred by Dr. Jason Mixter.

*1st Attack*, November 1933. Sudden attack of pain in left side of face, behind eyeballs; pain in both inguinal regions radiating into testicles. Pain severe for 6 hours. No residuals after 24 hours. No treatment.

*2nd Attack*, January 1936. Onset of severe vertex headache. The following day pain in low back and inguinal regions. Treated symptomatically. Returned to work after 10 days with minor headache and low back pain.

*3rd Attack*, March 1936. Abrupt onset of severe headache and discomfort in low back area. After 24 hours pain radiated into sacrum and down the left leg posteriorly. Patient remarked that "sudden movement or coughing caused a simultaneous exaggeration" of his vertex headache and left sciatica. Hospitalized. Spinal fluid: pressure 200 mm. water; fluid bloody; contained 216 WBC, with 53 per cent lymphocytes; Pandy ++++. No objective neurologic handicaps. Fluid cleared as did his headaches and sciatica after the third spinal puncture. Each puncture was performed on consecutive days. Patient had a fourth spinal fluid study 6 months later in an asymptomatic period. Queckenstedt test, omitted purposely initially, was at this time normal, as was complete microscopic and chemical examination of the fluid. It was the neurologist's opinion that a spinal cord tumor could be excluded at that time.

*4th Attack*, Nov. 23, 1936. Sudden onset of violent sacral pain with an associated severe headache. After a week, because of the increasing intensity of symptoms, he was hospitalized. Spinal fluid grossly bloody; Pandy ++; pressure 180 mm. water. Symptoms subsided after the one puncture.

*Myelography.* Dr. J. B. Ayer: "No block on spinal puncture. Lipiodol. Obstruction, L1 level."

*Laminectomy* by Dr. William J. Mixter, April 9, 1937. Lumbodorsal level. Intact total extirpation of neurofibroma.

*Results* 13 years after operation. No recurrence of symptoms. No neurological objective symptomatology.

*Comment.* As illustrated in all of these cases, it has been contrast radiologic studies that have established the diagnosis. If one reviews one's experiences in spontaneous subarachnoid hemorrhages one finds that lumbar-sacral radicular complaints are no rarity in the conscious patient. This is logically explained on the basis of low spinal nerve root irritation from the hemolyzed blood. One theoretical answer for the lumbar lower extremity pain has been that these patients may have had some pre-existing minor mechanical nerve root compression. This lumbar-sacral nerve root pain is common following cerebellar craniotomies and is often relieved by the lumbar drainage of bloody spinal fluid. In the abrupt spinal bleeding in cases of tumor of the cauda equina the nerve root pain is much more severe and offers much greater therapeutic competition than any other of the painful spinal root situations. One cannot rely on manometric evaluations for the diagnosis of these tumors in the lumbar region that precipitate ruptures of the blood vessels. Queckenstedt's test at the time of the impulsive bleeding may be omitted because of the disturbing measurable increase in intracranial pressure as recorded on the attached spinal manometer cylinder. These manometric studies even in the hemorrhagic phase may be normal. Spinal fluid protein determinations in the acute condition are unreliable because of the volume of blood mixed with the spinal fluid. Spinal fluid studies, in the interval of freedom from lower extremity pains and headaches, can be perfectly normal both physically and chemically. Thus the early recognition of this syndrome hinges on contrast myelography. Even though some spinal cord implications were objectively evidenced at some period in the clinical course of 2 of the 5 cases, the conclusive lead to the final diagnosis in all instances was obtained by myelography.

*Case 4.* #42-687. Male, aged 12 years. First seen Sept. 24, 1942. Referred by Dr. J. T. McCall.

*1st Attack*, 1938. Acute onset of headache, nausea and vomiting. Pain in low back, radiating into buttocks. Spinal puncture reported as "bloody and the pressure increased." Body plaster cast for a week. Two subsequent spinal punctures at 2-day intervals revealed changes in the fluid similar to initial diagnostic puncture. Cerebral and low back sciatic symptoms relieved following each spinal tap. No residual physical handicaps.

*2nd Attack*, Sept. 19, 1942. Abrupt onset of pain in left leg, and low back. Followed by stiffness of neck and headache. Low back spasticity and opisthotonos obviated spinal puncture under novocain local anesthesia, and 3rd lumbar puncture was performed under pentothal narcosis. Pressure: 430 mm. water. Queckenstedt omitted as being contra-indicated. Grossly bloody fluid. Symptoms disappeared remarkably following puncture.

*Laminectomy* by Dr. Barnes Woodhall, Nov. 16, 1942. L2–3 level. Complete removal of tumor.

*Histology.* Ependymoma (Fig. 1).

*Results* 8 years after operation. No recurrence of symptoms. No motor, sensory, or sphincter residuals.

*Comment.* If one could add to the dominant clinical characterizations of these spinal cord tumors, it would be the statement that these patients exhibit no objective neurologic evidences in the early phases of the recurrent spinal hemorrhages implicating lumbar spinal cord levels. The symptomatology, in the early manifestation of this disease, is such as to suggest a cerebral origin for the bleeding. The high spinal fluid pressure, the intensity of the headaches and even the appearance of optic nerve swellings (Case 3) logically center attention on a cerebral origin for these patients' complaints. The intensity of the radicular distress in the period of hemorrhage appears to be a clue to the diagnosis. This sciatic pain, dominantly unilateral or bilateral, is of such a severe character as to produce malignant irreducible opisthotonos, and intense muscular irritations which involve one or both lumbar lower extremity muscle groups. This pain may be paroxysmal. It may be spontaneous or initiated on sensory irritation of the skin of the lower extremities or buttocks. Its violence may be of such a character as to be in the category of the pain of child-birth. This spinal nerve root reaction strikes without warning, without any necessary physical antecedents and may persist for many days. Apparently the pain can be allayed by spinal fluid drainage. The headaches from which these patients may suffer are in the same category as the throes from spontaneous subarachnoid leakage of a ruptured cerebral blood vessel.

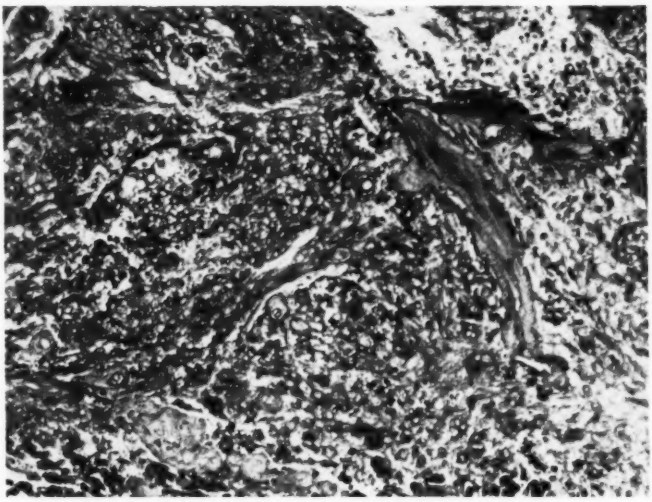

FIG. 1. *Case 4.* Photomicrograph of ependymoma (×180).

The objective evidences of profound Kernig and Brudzinski reactions serve as misleading neurologic findings. The vomiting characteristic of increased intracranial pressure is explained on the finding of an increased manometric spinal fluid pressure or the presence of "choked disks." Both of these objective evidences serve to further direct the examiner's attention away from the spinal cord pathology. The development of cranial nerve alterations results from the arachnoidal reaction to the irritative blood or its by-products within the subarachnoid absorptive spaces. These serve as further diagnostic misleads. At any rate, the sudden appearance of severe lower extremity radicular pain associated with deflagrating headaches should call to one's diagnostic mind the possibility of the existence of a low-placed spinal cord tumor that has initiated a spontaneous spinal hemorrhage.

*Case 5.* #46-222. Female, aged 18 years. Referred by Dr. S. D. Brown, Royston, Georgia, Feb. 24, 1946.

*1st Attack*, August 1944. Abrupt onset of intense lumbar, gluteal, thigh pain with severe cervico-occipital distress. Duration 10 days. No subjective motor, sensory or sphincter handicaps.

FIG. 2. *Case 5.* Myelogram showing obstruction to lipiodol. Repeated manometric studies had given no intimation of this block.

*2nd Attack*, November 1944. Again lumbosacral radiculitis pain and rigorous cephalalgia. Less severe and of shorter duration than initial upset. Again no motor, sensory or sphincter dysfunctions.

*3rd Attack*, Feb. 12, 1946. More intense attack than previously. Lumbago, bilateral hip, thigh pain. Occipitofrontal headache. Right tinnitus. Blurred vision. Bilaterally choked disks with retinal hemorrhages. Hyperreflexia with absent abdominal responses. Kernig and Brudzinski positive bilaterally. Spinal fluid bloody: pressure 330 mm. water. No block on Queckenstedt test. Decompression considered. Symptoms rapidly subsided. Spinal tumor suspected. Spinal puncture May 10, 1946: fluid clear; pressure 150 mm.; total protein, 38 mg. per cent. No manometric signs of spinal cord obstruction. Optic fundi normal. Cord tumor diagnosis excluded.

*4th Attack*, May 21, 1946. Acute bilateral lumbago-sciatica. No headache. Spinal fluid bloody: pressure 270 mm. water. No obstruction to bilateral jugular compression. Injection of 2 cc. lipiodol: total obstruction to oil on fluoroscopy (Fig. 2).

*Laminectomy*, May 30, 1946. Filum terminali tumor, L2 level. Complete removal.

*Histology.* Ependymoma (Fig. 3).

*Results* 5 years after operation. No neurologic objective residuals. No objective or subjective neurologic or physical symptomatology.

## SUMMARY

It seems definite from a detailed study of 5 cases of cauda equina tumors associated with spinal subarachnoid hemorrhages that the symptomatology of these growths in their early development is entirely subjective. There is no intimation in the beginning of this disease of any motor, sensory or

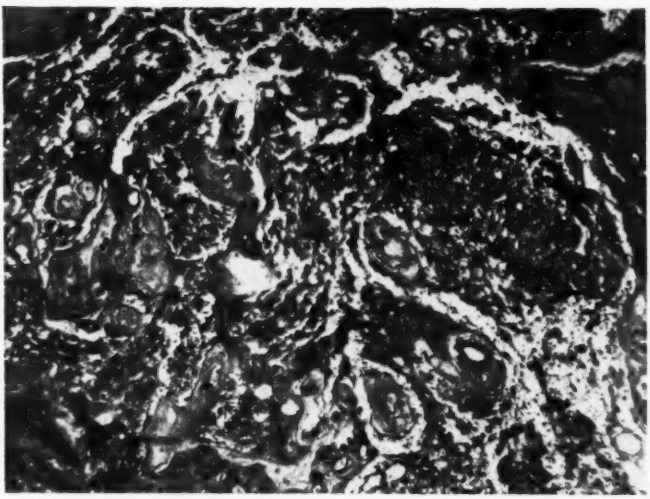

FIG. 3. *Case 5.* Photomicrograph of ependymoma (×100).

TABLE 1

*Summary of 5 cases of spinal cord tumor with spontaneous subarachnoid hemorrhage*

| Case | No. of Attacks | Maximal C.S F. Pressure Recorded | Character C.S.F. Fluid | Mano-metrics | Objective Spinal Cord Symp-toms | Myelog-raphy | Location of Tumor | Pathology |
|---|---|---|---|---|---|---|---|---|
| 1 | 4 in 12 years | Not reported | Blood: 3 separate occasions | Not reported | Yes | Lipiodol | L2, 3 | Neuroglioma |
| 2 | 25+ in 1½ years | Over 300 mm. | Blood: 4 separate occasions | No block | No | Lipiodol | L1, 2, 3, 4 | Ependymoma |
| 3 | 4 in 4 years | 200 mm. | Blood: 4 separate occasions | No block | No | Lipiodol | D12, L1 | Neurofibroma |
| 4 | 2 in 4 years | 400 mm. | Blood: 4 separate occasions | No block | Hypo-reflexia | Lipiodol | L2, 3 | Ependymoma |
| 5 | 4 in 2 years | 320 mm. | Blood: 2 separate occasions | No block | No | Lipiodol | L2 | Ependymoma |

sphincteric spinal cord dysfunctions. The diagnosis should be suspected on the appearance of one or more bouts of intractable lower extremity pain and an accompanying profound cephalalgia. The development of spontaneous subarachnoid bleeding in these patients as disclosed on spinal puncture should indicate the diagnosis. This bloody spinal fluid should prompt early myelographic contrast studies before compressive or destructive spinal nerve root symptoms are in objective evidence. A syndrome is defined by Webster as "a group of signs and symptoms that occur together and characterize a disease."

## REFERENCES

1. Abbott, K. H. Subarachnoid hemorrhage from an ependymoma arising in the filum terminale. Report of case. *Bull. Los Angeles neurol. Soc.*, 1939, *4:* 127–132.
2. André-Thomas, Ferrand, Schaeffer, and de Martel. Syndrome d'hémorragie méningée réalisé par une tumeur de la queue de cheval. *Paris méd*, 1930, *77:* 292–296.
3. Bailey, P. A study of tumors arising from ependymal cells. *Arch Neurol. Psychiat., Chicago*, 1924, *11:* 1–27.
4. Mallory, F. B. Three gliomata of ependymal origin: two in the fourth ventricle, one subcutaneous over the coccyx. *J. med. Res.*, 1902, *8:* 1–10.
5. Woodhall, B. Personal communication. Copy of records. Histologic slides. Sept. 1950.

# AN EXPERIMENTAL EVALUATION OF CERTAIN CONTRAST MEDIA USED FOR CEREBRAL ANGIOGRAPHY

## ELECTROENCEPHALOGRAPHIC AND HISTOPATHOLOGICAL CORRELATIONS

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SINCE the introduction of percutaneous techniques, cerebral angiography has become a commonplace diagnostic procedure. That the procedure is not without untoward sequelae is indicated by scattered reports in the literature.[6,7,9,10,13,16,18] It is probable that these reactions are even more common than reports indicate.

Several studies have attempted to evaluate the effects of substances used as contrast media. Thus, peripheral pharmacological effects on the cardiovascular system have been investigated.[8,12,14,17] Histopathological studies of the effect of these substances on the cerebral vessels were carried out by Kristiansen and Cammermeyer[15] with essentially negative findings. Broman, using the dye indicator technique, has extensively investigated alterations in permeability of the cerebral vessels caused by many substances including the Diodrast group of compounds.[2,3,4,5] In a previous report we have described a method of study combining the dye indicator technique with concomitant electroencephalography.[1]

This report presents results of the application of this technique to the evaluation of some common contrast media and three non-iodinated homologues of these compounds. In addition, correlative histopathological data are presented.

## METHOD

The technique employed was briefly as follows: Experiments were carried out on adult rabbits weighing between 2000 and 3000 gm. Under light nembutal and local procaine anesthesia a common carotid artery was isolated and catheterized with small polyethylene tubing, and branches of the external carotid were ligated. Tracheotomy was performed, and all animals were curarized and placed on mechanical respiration. Test substances were generally administered via the catheter over a 30 sec. period, excepting those instances where divided doses were used. All test injections were controlled with equivalent amounts of Ringer's solution.

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One hundred to 200 mg. of the tetra-sulfonic acid of copper phthalocyanine were injected intravenously. As with other anionic, organic substances,[11] the cerebral vessels are normally impermeable to this dye. EEGs were obtained continuously during the course of the experiment.

At the conclusion of each experiment the animal was sacrificed by stopping the respirator. All brains were immediately removed and appropriately fixed so that hematoxylin and phloxin, unstained frozen, Pickworth's benzidine, and Eros' fuchsin preparations could be obtained. Brains were selected from each group for celloidin Nissl preparations.

The substances tested fell into several chemical groups. Pyridine derivatives were represented by Diodrast® (diethanol amine salt of 3.5 diiodo-4-pyridine-N acetic acid) in 35 per cent, 50 per cent and 70 per cent solutions (w/v). The 35 per cent solution contains 0.17 gm. of iodine per cc. Neoiopax® (3.5 diiodo-4-pyridoxyl-N-methyl-2-6-carboxylic acid) was used in 37.5 per cent (w/v) concentration in Ringer's solution. The iodine content is approximately 0.18 gm. per cc. We were unable to obtain the non-iodinated homologues of these two compounds. N-methyl nicotinamide hydrochloride, a pyridine derivative and a normal body metabolite, was used as an approach to these structures. This was administered in a 20 per cent solution (w/v).

The benzene derivatives used were: Urokon® (3-acetyl-amino-2-4-6-triiodo sodium benzoate) in 30 per cent solution (w/v) at both pH 5.4 and 7; its non-iodinated homologue,* prepared in 20 per cent solution (w/v) and adjusted to pH 7.4; and para-amino-hippurate (para-amino-benzolyl glycerine) in 20 per cent solution (w/v). Urokon contains 0.19 gm. of iodine per cc.

In order to tabulate these data, the following classifications have been set up:

*Electroencephalogram*

0 = No change.
1+ = Amplitude decrease or transient delta activity lasting less than 5 min.
2+ = Focal delta activity or generalized slow activity lasting 5 to 10 min.
3+ = Slow activity or abolition of activity persisting up to 1 hr.

Seizure discharges are not included in this classification and are tabulated separately. In general, when these occurred they were associated with severe EEG abnormalities.

*Gross Staining with Copper Phthalocyanine (Increased Vascular Permeability)*

1+ = Slight staining of a portion of one hemisphere.
2+ = Moderate staining usually involving most of one hemisphere.
3+ = Intense staining usually involving more than one hemisphere, i.e., staining of the opposite hemisphere and/or posterior fossa contents.

* Kindly furnished by Mallinckrodt Chemical Works, St. Louis, Missouri.

*Histopathologic Changes*

These were confined, in the main, to edema, vascular congestion and hemorrhage. They are graded according to severity:

0 = No change.

3+ = Presence of all three alterations.

These changes will be described in more detail subsequently.

## RESULTS

The results of the various experiments are tabulated in Tables 1, 2, 3 and 4.

*Electroencephalographic Changes.* In general, the severity of these changes paralleled the administered dose of the particular compound tested. From Table 1 it may be seen that only 2 of 6 animals receiving 460–690 mg. per kg. of 35 per cent Diodrast showed as much as 1+EEG changes. Of 11 animals receiving 920 mg. per kg. of this substance, 1 animal showed no EEG change, 1 showed slight change, 2 had moderate changes, and severe changes occurred in the remaining 7. Five of the 11 had seizures.

Four animals (Table 1) received 660 mg. per kg. of 50 per cent Diodrast;

TABLE 1

| Compound | No. of Animals | Dose 1 kg. | EEG Changes | No. with Seizures | Staining | Microscopic Changes |
|---|---|---|---|---|---|---|
| Diodrast 35% | 6 | 460–690 mg. | 0 (4)<br>1+(2) | 0 | 0 | 0 |
| | 5 | 920 mg. | 2+(1)<br>3+(4) | 3 | 1+(3)<br>2+(2) | 0 (2)<br>1+(2)<br>3+(1) |
| Diodrast 35% with 10% $CO_2$ 90% $O_2$ inspired | 6 | 920 mg. | 0 (1)<br>1+(1)<br>2+(1)<br>3+(3) | 2 | 0 (4)<br>1+(2) | 0 (4)<br>1+(1)<br>3+(1) |
| Diodrast 50% | 4 | 660 mg. | 0 (1)<br>2+(2)<br>3+(1) | 1 | 0 (1)<br>1+(2)<br>2+(1) | 0 (3)<br>3+(1) |
| | 5 | 920 mg. | 2+(1)<br>3+(4) | 3 | 1+(1)<br>2+(1)<br>3+(3) | 0 (1)<br>3+(4) |
| Diodrast 70% | 1 | 310 mg. | 3+(1) | 1 | 2+(1) | 0 |
| | 2 | 460 mg. | 3+(2) | 2 | 2+(1)<br>3+(1) | 2+(1)<br>3+(1) |
| | 3 | 920 mg. | 3+(3) | 0 | 3+(3) | 3+(3) |
| Neoiopax 37.5% | 3 | 460 mg. | 3+(3) | 0 | 3+(3) | 3+(3) |

1 was unchanged, 2 were moderately changed, and 1 was severely changed. Seizures occurred in 1 instance. Five animals received 920 mg. per kg. and all but 1 had severe EEG changes—3 animals had seizures.

Severe EEG changes occurred in all of the 6 animals receiving from 310–920 mg. per kg. of 70 per cent Diodrast. Three of the 6 animals had seizures.

Severe EEG abnormalities were produced by 460 mg. per kg. of 37.5 per cent Neoiopax in each of 3 animals. Electrical fits occurred in none.

Two animals (Table 2) received large amounts per kg. of Diodrast in small increments spaced over relatively long intervals (10–30 min.) without significant EEG changes. However, an equivalent amount in one injection produced profound changes. Both these animals had seizures. Two animals (Table 2) received 70 per cent Diodrast in increments of 70 mg. at 20-sec.

TABLE 2

| Compound | No. of Animals | Time | Dose | EEG Changes |
|---|---|---|---|---|
| Diodrast 35%<br>Time elapsed from first injection | 1 | 0<br>22 min.<br>57 min. | 460 mg.<br>460(920)<br>920(1840) | 0<br>0<br>3+(1) |
| Diodrast 70%<br>Divided doses 20 seconds apart | 2 | 0<br>20 sec.<br>40 sec.<br>60 sec.<br>80 sec.<br>100 sec.<br>120 sec. | 70 mg.<br>70(140)<br>70(210)<br>70(280)<br>70(330)<br>70(420)<br>70(490) | 0<br>0<br>0<br>0<br>0<br>0<br>3+(2) |
| Time elapsed from first injection | 1 | 0<br>10 min.<br>35 min.<br>50 min. | 140 mg.<br>280(420)<br>420(840)<br>940(1780) | 0<br>0<br>0<br>3+(1) |

intervals without significant electrical abnormalities. Seizures occurred only after receiving 490 mg. per kg.

From Table 3 it may be seen that of 3 animals receiving 115 mg. per kg. of 30 per cent Urokon, only 1 had severe changes. A dose of 230 mg. per kg. of the same drug produced severe EEG changes in 4 of 6 animals, and 1 had seizures. Injections of 460 mg. per kg. produced severe abnormalities in each of 9 animals; 6 had seizures. Division of this same amount into increments moderated the changes in only 2 of the 5 animals.

Fifteen animals received equivalent amounts on a mg. per kg. basis of 20 per cent solutions of non-iodinated compounds (Table 4). Of these, all but 4 had severe changes—only 2 had no changes.

*Gross Staining with Vital Dye.* It may be seen in Table 1 that 35 per cent Diodrast in amounts from 460–690 mg. per kg. produced no staining. Of 11 animals injected with 920 mg., 6 received 10 per cent $CO_2$—4 of these

were unstained and 2 stained only slightly. All 5 of the animals that received no $CO_2$ were stained.

Three of 4 animals receiving 660 mg. of 50 per cent Diodrast were stained. Of 5 animals receiving 920 mg., all were stained, 4 severely.

TABLE 3

| Compound | No. of Animals | Dose 1 kg. | EEG Changes | No. with Seizures | Staining | Microscopic Changes |
|---|---|---|---|---|---|---|
| Urokon 30% pH 5.4 | 3 | 115 mg. | 0 (1)<br>1+(1)<br>3+(1) | 0 | 0 (1)<br>1+(2) | 0 (2)<br>1+(1) |
| | 4 | 230 mg. | 3+(4) | 1 | 2+(1)<br>3+(3) | 2+(1)<br>3+(2) |
| | 2 | 230 mg.* | 2+(2) | 0 | 1+(1)<br>2+(1) | <br>3+(1) |
| | 4 | 460 mg. | 3+(4) | 3 | 3+(4) | 2+(1)<br>3+(1) |
| Urokon 30% pH 7† | 5 | 460 mg. | 3+(5) | 3 | 2+(1)<br>3+(4) | 3+(5) |
| Divided dose‡ | 5 | 460 mg.‡ | 2+(1)<br>3+(4) | 2 | 0 (1)<br>1+(4) | 0 (4)<br>1+(1) |

The figures in parentheses are the number of animals showing the indicated change.
* Divided into 3 parts given in 10 sec. at 10 sec. intervals.
† Supplied by Mallinckrodt Chemical Works, St. Louis, Missouri.
‡ Divided into 4 parts given in 8 sec. at 30 sec. intervals.

TABLE 4

| Compound | No. of Animals | Dose 1 kg. | EEG Changes | No. with Seizures | Staining | Microscopic Changes |
|---|---|---|---|---|---|---|
| 3 acetylamino-benzoic acid 20%, pH 7 | 8 | 160 mg. | 0 (1)<br>2+(1)<br>3+(6) | 0 | 0 (2)<br>1+(1)<br>2+(4)<br>3+(1) | 0 (3)<br>1+(2)<br>2+(2)<br>3+(1) |
| Para-amino-hippurate 20% | 3 | 184 mg. | 3+(3) | 0 | 1+(1)<br>2+(1)<br>3+(1) | 0 (1)<br>1+(1)<br>3+(1) |
| N-methyl nicotinamide 20% | 4 | 194 mg. | 0 (1)<br>2+(1)<br>3+(2) | 1 | 0 (2)<br>2+(1)<br>3+(1) | 0 (2)<br>2+(1)<br>3+(1) |

Seventy per cent Diodrast administered to 6 animals in amounts varying from 310–920 mg. per kg. produced moderate staining in 2 and severe staining in 4.

Thirty per cent Urokon at several dosage levels produced staining in 21

of 23 animals (Table 3). The degree of staining was somewhat less in those animals receiving equivalent amounts in divided doses. The results were not significantly altered by variations in the pH.

Of the 15 animals receiving non-iodinated compounds 11 showed staining (Table 4).

Metrazol convulsions (not tabulated) were induced in 6 animals by either

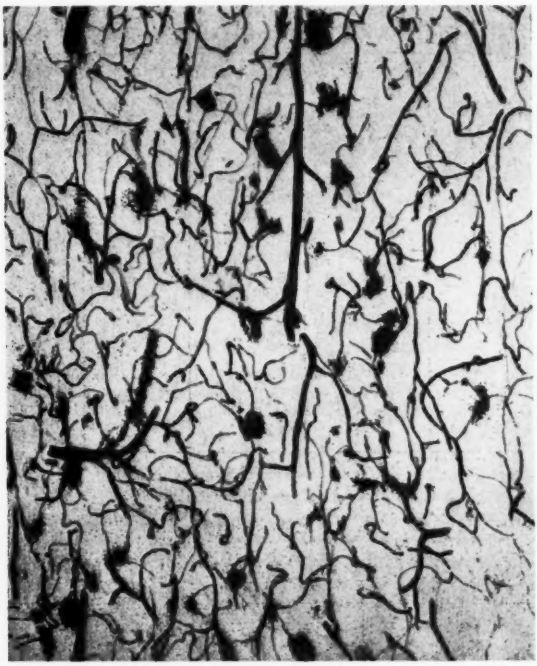

FIG. 1. Basal ganglion showing vascular dilatation and multiple petechial hemorrhages. Eros, ×67.

intracarotid or intravenous administration and in none was staining noted.

*Histopathologic Studies.* In general, the microscopic pathology closely paralleled the changes indicated by the gross staining and the EEG abnormalities. For purposes of correlation, the observations have been considered under three headings, namely: (1) Changes in the vascular bed, (2) parenchymal edema, and (3) tissue staining with the dye.

Certain general features hold for all of these changes. The vascular injury, edema and staining were almost entirely confined to the gray matter—cortex and deep nuclear masses. Vasodilatation and staining were observed in 1 animal sacrificed as early as 1 min. after injury.

(1) Changes in the vascular bed: The early changes in the vasculature consisted of uniform dilatation of parenchymal vessels of all calibers (Fig. 1).

At a later stage stasis became evidenced by conglutination of masses of red cells and pooling of plasma. Ball-shaped hemorrhages of varying size were almost always present in specimens presenting significant alterations of the vessels.

(2) Parenchymal edema: Moderate injury produced focal and perivascular edema. With more severe injury the edema was diffuse and widespread. Characteristic swelling of the oligodendroglia was an early change. A more

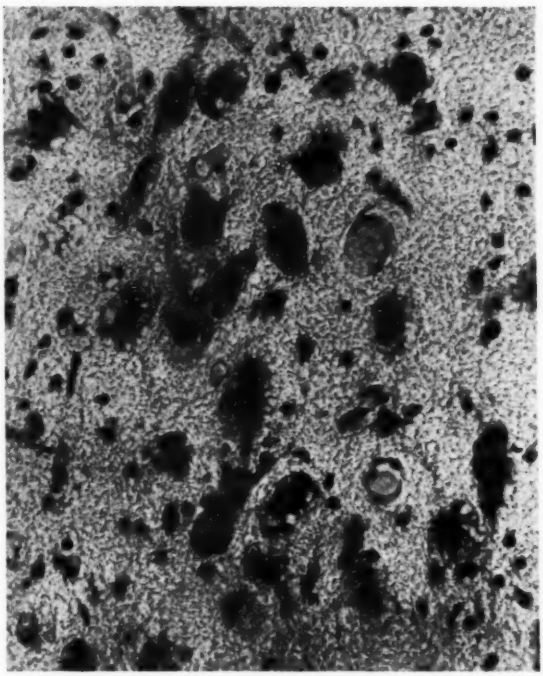

FIG. 2. Basal ganglion showing edema. The neurones are difficult to recognize because of the advanced degree of intracytoplasmic vacuolization. Thionin, ×306.

significant functional injury was evidenced by neuronal swelling, from perinuclear halo formation to virtual replacement of the cell body by a honeycomb of vacuoles (Fig. 2).

(3) Tissue staining with the dye: Never, in the normal brain, was there evidence of staining of the vessels or parenchyma with the dye. With injury (Fig. 3), the intensity of the staining was dependent upon two factors—the degree of vascular damage and the concentration of the circulating dye. The tissue affinity for the dye appeared in the following descending order: endothelial cell nuclei, neurones, and glia.

## DISCUSSION

These studies have not included the effects of osmotic pressure or pH per se; however, Broman[5] found that neither was a critical factor and could be varied within rather wide limits without significant alterations in vascular permeability.

The partial protection afforded by inspired $CO_2$ is probably best explained by the "diluting and washing out" effect consequent to increased

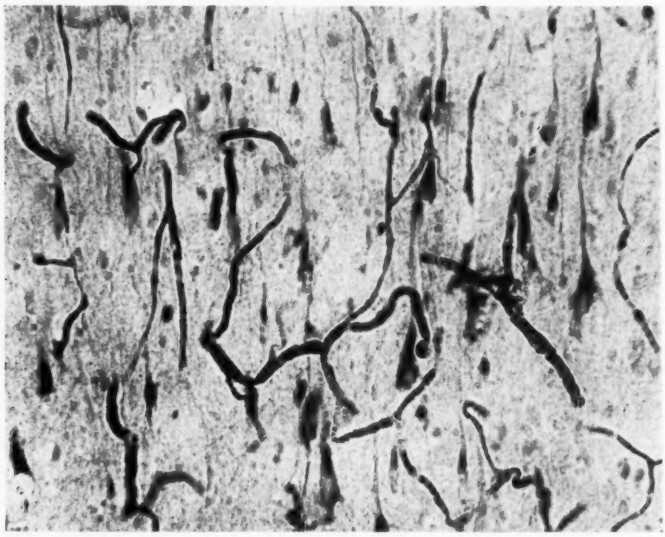

FIG. 3. Cortex showing staining in an injured brain. The circulating copper phthalocyanine has passed the blood-brain barrier and stained the neurones a delicate blue. Red cells in vessels have been stained a brilliant red by the acid fuchsin. Eros, ×263

cerebral blood flow. This hypothesis is substantiated by a converse experiment of Broman's[2] in which increased injury to the cerebral vessels occurred when stasis was produced by occlusion of the cephalic afferent vessels.

It is interesting to note that most investigators[12,14,17] concur that the effect of Diodrast and similar substances upon the peripheral vessels is primarily one of vasodilatation. Our histologic observations give us no cause to believe that the cerebral vessels of the rabbit react differently.

Because metrazol-induced convulsions produce no evidence of blood-brain-barrier breakdown, it is improbable that the presence or absence of fits alter the interpretation of the data. The seizures are a result, rather than a cause, of vascular injury.

During the later phases of this work, studies with Diodrast have been carried out upon 8 young adult *Macacus rhesus* monkeys. These qualitative studies indicate entirely similar alterations in vascular permeability and

consequent staining with copper phthalocyanine. Microscopically, no distinction is noted from the changes in the vascular bed, parenchymal edema, and tissue staining with the dye noted in the rabbits. Again, when alterations in vascular permeability occurred they were accompanied by comparable changes in the EEG. Sufficient data in this species are not available to quantitate end-points in terms of dosage administered, but the results are confirmatory.

## SUMMARY AND CONCLUSIONS

The EEG abnormalities parallel the findings by the dye indicator technique and the pathologic changes. All of the contrast media and their non-iodinated chemical homologues were capable of producing severe abnormalities in cerebral electroactivity and vascular permeability. The severity of injury varies directly with the amount and concentration administered. A larger amount (mg. per kg. basis) of contrast medium is tolerated when administered in small increments—the longer the elapsed time between increments, the greater the tolerance.

Although the number of experiments is small, it appears that the vascular damage caused by a known toxic quantity of contrast medium can be reduced by $CO_2$ administration.

Of the media tested, Diodrast is the least noxious. On a mg. per kg. basis, a 35 per cent solution is tolerated by rabbits in amounts that are approximately twice the equivalent of that ordinarily used in human cerebral angiography.

The histologic findings suggest a selective toxic action of these agents upon the cerebral vascular bed with (1) early vasodilatation or loss of tone, which may progress to ultimate stasis, (2) severe alteration of the permeability of the vessels, and (3) progressive cerebral edema consequent upon these changes.

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## REFERENCES

1. Bloor, B. M., Wrenn, F. R., Jr., and Hayes, G. J. An experimental method for the evaluation of contrast media used in cerebral angiography. *J. Neurosurg.*, 1951, *8:* 435–440.
2. Broman, T., Forssman, B., and Olsson, O. Further experimental investigations of injuries from contrast media in cerebral angiography. Summation of various injurious factors. *Acta radiol., Stockh.*, 1950, *34:* 135–143.
3. Broman, T., and Lindberg-Broman, A. M. An experimental study of disorders in the permeability of the cerebral vessels ("the blood-brain-barrier") produced by chemical and physico-chemical agents. *Acta physiol. scand.*, 1945, *10:* 102–125.
4. Broman, T., and Olsson, O. The tolerance of cerebral blood-vessels to a contrast medium of the Diodrast group. An experimental study of the effect on the blood-brain-barrier. *Acta radiol., Stockh.*, 1948, *30:* 326–342.
5. Broman, T., and Olsson, O. Experimental study of contrast media for cerebral angiography with reference to possible injurious effects on the cerebral blood vessels. *Acta radiol., Stockh.*, 1949, *31:* 321–334.
6. Chusid, J. G., Robinson, F., and Margules-Lavergne, M. P. Transient hemiplegia associated with cerebral angiography (diodrast). *J. Neurosurg.*, 1949, *6:* 466–474.

7. Dunsmore, R., Scoville, W. B., and Whitcomb, B. B. Complications of angiography. *J. Neurosurg.*, 1951, *8:* 110–118.
8. Edwards, E. A., and Biguria, F. A comparison of skiodan and diodrast as vasographic media, with special reference to their effect on blood pressure. *New Engl. J. Med.*, 1934, *211:* 589–593.
9. Engeset, A. Cerebral angiography with perabrodil (carotis angiography). *Acta radiol., Stockh.*, 1944, supp. 56, 207 pp.
10. French, L. A., and Blake, P. S. Complications following the use of neo-iopax in cerebral angiography. *Amer. J. Roentgenol*, 1950, *64:* 816–818.
11. Friedemann, U. Blood-brain barrier. *Physiol. Rev.*, 1942, *22:* 125–145.
12. Gordon, A. J., Brahms, S. A., Megibow, S., and Sussman, M. L. An experimental study of the cardiovascular effects of diodrast. *Amer. J. Roentgenol.*, 1950, *64:* 819–830.
13. Green, J. R., and Arana, R. Cerebral angiography. A clinical evaluation based on 107 cases. *Amer. J. Roentgenol.*, 1948, *59:* 617–650.
14. Heathcote, R. St. A., and Gardner, R. A. Abrodil: an experimental investigation. *Brit. J. Radiol.*, 1931, n.s. *4:* 641–651.
15. Kristiansen, K., and Cammermeyer, J. An experimental investigation on the effect of arteriography with perabrodil on the brain. *Acta radiol., Stockh.*, 1942, *23:* 113–130.
16. Olsson, O. Cerebral angiography: tolerance for contrast media of Diodrast type. *J. Neurol. Neurosurg. Psychiat.*, 1949, n.s. *12:* 312–316.
17. Weatherall, M. The pharmacological actions of some contrast media and a comparison of their merits. *Brit. J. Radiol.*, 1942, *15:* 129–137.
18. Wilkinson, M., Stanton, J. B., Jones, D. P., and Spalding, J. M. K. Percutaneous carotid angiography. A team technique. With a report of the results in seventy cases. *J. Neurol. Neurosurg. Psychiat.*, 1949, n.s. *12:* 183–186.

# THE VALUE OF ELECTROMYOGRAPHY IN NEUROLOGY AND NEUROSURGERY*

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It is the purpose of this paper to survey the increasing value of electromyography as an aid in the field of neurologic diagnosis. In 1943 Weddell, Feinstein and Pattle[27] presented some of the clinical applications of electromyography. Since then much valuable investigative work has been done.[1–28] It would seem timely, therefore, to present a systematic review of how the electromyograph can be of practical use to the clinical neurologist and the neurosurgeon. This practical value largely depends on detecting the presence or absence of lower motor neuron disease which evidences itself by denervation fibrillation potentials accurately recorded both visually and acoustically by the electromyograph. It should be emphasized, however, that electromyography, like any other laboratory procedure, is in no way a substitute for a careful anamnesis and meticulous neurologic examination.

It is now generally accepted that for accurate electromyography it is necessary to use a needle electrode placed directly into the muscle to be tested, rather than the older method using a percutaneous electrode. The authors prefer the Meditron Clinical Electromyograph, Model 201, which utilizes a monopolar needle electrode, a cathode ray oscilloscope, a sensitive sound amplifier and a myoscope.

We have used this instrument to examine patients with the usual wide variety of disorders seen in the practice of clinical neurology and neurosurgery. We have been surprised by the amount of useful diagnostic information obtained. Many puzzling problems that could not be accurately diagnosed by ordinary clinical means fell, logically, into their proper classification with the information given us by the electromyograph. We shall attempt to present the bioelectric findings in diseases of the nervous system, and to point out features that have proved useful in differential diagnosis.

A detailed description of the Meditron Clinical Electromyograph, and the methods used in its clinical application, have been recently published.[22] In addition, a myoscope is now available which permanently records, by means of a magnetic tape, electromyographic patterns. This tape can be played back through the instrument and faithfully reproduces, visually and acoustically, the muscle action potentials as recorded at the time of the original examination.

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## CLINICAL OBSERVATIONS

Those diseases of the spinal cord that affect the anterior horn cells often are not only diagnostically confusing, but difficult to detect in their early stages. Since one of the causes of denervation fibrillation is anterior horn cell damage, it is often possible, with the electromyograph, to detect minimal or early involvement where the classical clinical signs are absent. We have found this of particular value in cases in which the patient has been diagnosed as having a "functional" rather than an organic disorder. In other words, no true objective neurological abnormalities could be found, yet the patient's symptoms were corroborated as organic by the EMG findings of scattered lower motor neuron disease. Case 1 illustrates this point:

*Case 1.* Mrs. P., a 60-year-old white female, entered Mercy Hospital with the chief complaint of increasing weakness and numbness of both legs over a period of 6 months. She stated that these symptoms had come on gradually after the death of her husband, accompanied by nervousness and depression. The disability had progressed to the point where she could no longer climb stairs.

Neurological examination revealed only absent abdominal reflexes, diminished ankle jerks, and generalized weakness of the lower extremities without fasciculations or focal atrophies. The plantar responses were flexor. Vibratory and position sense were slightly diminished. No true loss of pain, touch or temperature sensation could be demonstrated. Ethyl iodophenylundecylate myelography was negative. A psychiatric diagnosis of psychoneurosis, conversion hysteria, was made.

The EMG, however, revealed evidence of diffuse lower motor neuron disease of all four extremities, more marked in the lower. A diagnosis of arteriosclerotic myelopathy was suggested. Subsequently the disease progressed to almost complete spastic paraplegia with bilateral extensor plantar responses.

## DEGENERATIVE DISEASES OF THE SPINAL CORD

The EMG achieves one of its most important functions in the diagnosis of degenerative diseases of the spinal cord. For example, in early *amyotrophic lateral sclerosis* clinical examination may reveal evidences of anterior horn cell damage only in the intrinsic muscles of the hands, whereas electromyographic examination demonstrates denervation fibrillation and fasciculation voltages in the lower extremities as well. Later in the disease the EMG continues to reveal this widespread anterior horn cell damage, even though it is impossible clinically to demonstrate it in the lower extremities because of the marked pyramidal tract involvement producing a spastic paraplegia. It should be emphasized that careful multiple needle insertions must be made in the various muscles in all four extremities in order to demonstrate these abnormal electrical impulses. This is necessary because the frequency of the diagnostic wave forms varies from muscle to muscle. Thus, multiple sampling becomes an indispensable feature of accurate electromyography. We have all seen patients who are suspected of having either amyotrophic lateral sclerosis or a cervical cord tumor. If denervation fibrillation and fasciculation voltages in such a patient are found in the lower extremities, the possibility of a cervical cord tumor is automatically ruled out.

The protean nature of *multiple sclerosis* makes the early diagnosis of this disease obviously difficult. Therefore, any corroborative evidence of diffuse central nervous system disease is of particular importance. The EMG, in patients suspected of having multiple sclerosis, often reveals diffuse lower motor neuron disease which cannot be demonstrated by clinical diagnostic methods. It should be emphasized, however, that electromyographic findings of diffuse lower motor neuron disease are in no way diagnostic of multiple sclerosis because, obviously, they may be found in any degenerative disease of the anterior horn cells. We have noticed, however, that in multiple sclerosis fasciculation voltages are never encountered whereas they are a characteristic finding in other chronic degenerative diseases of the spinal cord. Thus, in a young patient, with only a few signs and symptoms suggesting multiple sclerosis (possibly urinary urgency, questionable nystagmus and absent abdominal reflexes) the finding of diffuse denervation fibrillation without fasciculation voltages is very suggestive of the disease.

Similarly, in *subacute combined cord degeneration*, early diffuse lower motor neuron disease may be demonstrated despite meager clinical evidence. Again, this finding should be interpreted as suggestive but not conclusive.

*Progressive muscular atrophy* (whether the spinal form of Aran-Duchenne, the juvenile type of Werdnig-Hoffmann, the scapulohumeral type, or the bulbar form of Fazio-Londe) and *amyotrophic lateral sclerosis* are probably different manifestations of the same degenerative disease process. Electrically, certainly, the EMG findings would tend to confirm this concept since all of these forms, whether or not pyramidal tract involvement is present, show diffuse denervation fibrillation and fasciculation voltages indicating anterior horn cell involvement.

The value of the electromyograph in diagnosing progressive muscular atrophy is indicated by Case 2:

*Case 2.* A 46-year-old white male was referred by an insurance company because of weakness and atrophy of the right arm and hand. The patient stated that this disability first appeared after an auto accident in which he was purported to have injured his neck and back.

Neurological examination revealed atrophy of the intrinsic muscles of the right hand without sensory or reflex changes. There were no abnormalities of the cranial nerves. In particular no fasciculations of the tongue were noted. The remainder of the findings were negative, including flexor plantar responses bilaterally.

Widespread sampling of the muscles of all four extremities revealed diffuse denervation fibrillation and fasciculation voltages, most pronounced in the visibly atrophied muscles of the right hand. The insurance company was advised to withhold compensation in this case because the patient most probably was suffering from a degenerative disease of the spinal cord which could have no relationship to the alleged trauma. Over the period of the next year there developed the typical findings of progressive muscular atrophy (spinal form of Aran-Duchenne).

## INFECTIOUS AND INFLAMMATORY DISEASES OF THE SPINAL CORD

In infectious and inflammatory diseases of the spinal cord the EMG proves a useful diagnostic adjunct by indicating the extent of the disease

process and also by providing important prognostic information. For example, in *acute anterior poliomyelitis* the electromyographer can determine accurately the specific muscles affected, and also the amount of denervation of any particular muscle. It can readily be seen that this is important because it channels physical therapeutic efforts toward those muscles that are capable of regaining function. For instance if, in any given muscle, denervation fibrillation voltages are elicited in 100 per cent of all areas tested and with voluntary effort no discrete motor unit contractions are seen, then this muscle can be said to be hopelessly denervated and physical therapy useless. This, then, obviates the long, costly hours of physical therapy so often wasted on a particular muscle that can never regain function, and allows early orthopedic surgery without unnecessary delay. Conversely, oftentimes an apparently paralyzed muscle will be found to be only slightly denervated but rendered useless by psychologic inhibition. The patient, by watching and listening to the EMG, can readily be reeducated to contract this muscle once he, himself, recognizes that it is capable of contracting. Another important concept is that of Hipps, who has pointed out that there is often a segmental destruction of portions of the poliomyelitic muscle as seen on the operating table. We have confirmed this electromyographically, thus providing the surgeon with an opportunity to utilize the viable segments that remain.

Other inflammatory and infectious diseases of the spinal cord in which we have used the EMG to similar advantage are the *Guillain-Barré syndrome*, *herpes zoster*, *bacterial infections*, either diffuse or focal (intra- and extramedullary abscesses), and *luetic infections*, particularly in *tabes dorsalis*. In all of these diseases the presence and extent of the lower motor neuron involvement can be accurately determined and consequently an early and precise prognosis of the degree of return of function in any specific muscle can be made.

## TRAUMA TO THE SPINAL CORD

Trauma to the spinal cord often produces both upper and lower motor neuron injury. It is of practical importance to know the degree and extent of this injury. For example, in a paraplegic who has suffered a crush injury of the conus medullaris at the level of the first lumbar vertebra, it is of extreme prognostic value to determine whether or not there has been a complete transection or whether there are viable nerve pathways remaining that cannot be demonstrated clinically. If such pathways can be demonstrated, every effort can be concentrated on increasing the power of the partially innervated muscles. As in poliomyelitis, the psychologic effect is invaluable if it can be demonstrated, by having the patient watch and listen to the EMG, that he still has some remaining muscle function, even though at the time the muscle is apparently totally paralyzed.

## VASCULAR DISEASES OF THE SPINAL CORD

Our investigations with the electromyogram in vascular diseases of the spinal cord have revealed a surprising amount of damage to the motor cells

of the cord in elderly patients whose only systemic disease is diffuse arteriosclerosis. Many of these patients present symptoms that seem incompatible with the meager neurological findings. As we have mentioned (Case 1), these symptoms are often termed "functional". Also we are finding an increasing number of elderly patients who, apparently presenting only the neurologic picture of a pure corticospinal disease ("primary lateral sclerosis"), actually, on EMG examination, show a diffuse lower motor neuron disturbance which is masked, clinically, by the pyramidal tract signs. Thus we can confirm the concept that an *arteriosclerotic myelopathy*, probably on the basis of a circulatory insufficiency, can and does involve both levels of the motor system of the spinal cord. Therefore, in patients in the upper age group, presenting a confusing neurologic picture, we can often rule out functional disorders and establish a diagnosis of a true organic syndrome.

## TUMORS OF THE SPINAL CORD

Tumors of the spinal cord may frequently present an obscure neurologic picture which the EMG can often clarify. These tumors, other than intramedullary, almost always involve the spinal nerve roots and, therefore, produce localized denervation fibrillation in the muscles supplied by the involved roots.

The differential diagnosis between a *high extramedullary cervical cord tumor* and a degenerative cord disease without involvement of the cranial nerves (as frequently occurs in amyotrophic lateral sclerosis), is often difficult. This difficulty arises because in amyotrophic lateral sclerosis, for example, the upper motor neuron signs in the lower extremities obscure the lower motor neuron component. Utilizing the EMG, however, we find denervation fibrillation voltages widespread throughout the skeletal musculature in the degenerative disease (the muscles of the face are always tested), but in the high cervical cord tumor we find them confined only to the distribution of the involved cervical nerve roots.

*Case 3.* A 36-year-old white female entered with the chief complaints of difficulty in walking, weakness, wasting of the upper extremities, and pain in the occipitocervical region. These symptoms had been slowly progressive over a period of 4 years.

Examination showed no involvement of the cranial nerves. There was atrophy of the intrinsic muscles of the hands and of the arms with occasional fasciculations confined to these extremities. The lower extremities showed a spastic paraparesis with increased deep reflexes and bilateral extensor plantar responses. The abdominal reflexes were absent. There was localized tenderness on palpation of the upper cervical spinous processes and a persistent hypalgesia over the occiput. There were no other sensory disturbances. Cervical x-rays were negative. Pantopaque myelography was refused.

Electromyography revealed marked denervation fibrillation voltages in the muscles of all four extremities and the face, thus establishing the diagnosis of a diffuse degenerative disease rather than a cervical cord tumor. Recently obvious fasciculations of the tongue and lower extremities and typical bulbar speech have developed in this patient.

An *extradural tumor* in the cervical region may present the same symptoms and signs as a protruded cervical disc or an anterior scalene syndrome, namely, pain in the cervical region radiating to one or both upper extremities, accompanied by numbness, tingling and weakness. Sensory, motor and reflex changes may or may not be demonstrated. The extradural tumor may be differentiated by the EMG from the anterior scalene syndrome because the tumor will involve the nerve roots and, consequently, will cause denervation fibrillation of the posterior cervical muscles since they are innervated by the posterior primary divisions of the cervical nerves (emerging proximal to the brachial plexus). Similarly, a protruded disc will also result in denervation over the posterior primary divisions. On the other hand, pressure on the brachial plexus by an anterior scalene muscle cannot involve these posterior primary divisions; thus, a clearcut differential between an extradural spinal cord tumor (or a cervical disc) and an anterior scalene syndrome can be established by the EMG.

To differentiate an extradural tumor and a cervical disc electromyographically, we depend upon the fact that the cervical disc involves only one nerve root, almost invariably unilaterally. The tumor, however, can be shown to involve more than one root, often bilaterally, even though there are no clinical indications of this.

As in all of electromyography, caution must be exercised to sample the muscles extensively and to always bear in mind the possibility of the occasional anomalous innervation.

*Case 4.* A 63-year-old Greek male presented himself with the complaints of pain and weakness of both upper extremities for about 5 months. Past history was significant in that prostatic resection 5 years previously had revealed the presence of a malignant adenoma of that gland.

Examination demonstrated mild tenderness of the lower cervical spine, vague hypalgesia over the 4th, 5th and 6th cervical dermatomes, without reflex or motor changes. The pain in the upper extremities was not made worse by coughing, sneezing or straining nor by jugular compression. X-rays of the cervical spine revealed a partial collapse of the 3rd cervical vertebra without displacement and no other abnormalities. Pantopaque myelography, up to the foramen magnum, was completely negative without evidence of narrowing of the cervical canal.

Electromyography showed bilateral involvement of the muscles innervated by the 2nd through the 6th cervical nerve roots including the posterior primary divisions, thereby placing the lesion at or proximal to these divisions. With the above evidence, an extradural tumor was suspected. This was confirmed at operation when a metastatic prostatic adenoma was found extending extradurally from the 2nd to the 7th cervical vertebrae.

## THE SPINAL NERVE ROOT COMPRESSION SYNDROME

In conjunction with neurologic examination and pantopaque myelography, the electromyogram is proving a valuable aid in diagnosing the spinal nerve root compression syndrome. We wish to re-emphasize that the basis of the electromyographic localization of a single nerve root lesion is the finding of denervation fibrillation in those muscles supplied by that specifi

cally involved nerve root and in no other muscles. In other words, although an isolated muscle may have multiple nerve root innervation, it will show denervation fibrillation in common only with those other muscles that are innervated by the same compressed nerve root. To illustrate how a lesion compressing, for example, the 7th cervical nerve root may be localized by a process of elimination, the needle electrode is first placed in several areas of the deltoid and biceps muscles, innervated by the 4th, 5th and 6th cervical nerve roots. No denervation fibrillation voltages are found. Next, the electrode is inserted successively in the extensor carpi radialis, extensor communis digitorum, extensor carpi ulnaris, and the flexor carpi ulnaris (innervated by the 6th, 7th and 8th cervical nerve roots). In these muscles a maximum of denervation fibrillation voltages are noted. The next muscle tested is the abductor digiti quinti, innervated by the 8th cervical and 1st dorsal nerve roots. As in the first instance, no evidence of denervation is found in the muscle. The lesion, therefore, since we have demonstrated that the 5th, 6th and 8th nerve roots are not involved, must be compressing the 7th cervical nerve root. Examination of the erector colli musculature reveals segmental denervation fibrillation which confirms the fact that the lesion must involve the posterior primary division. In other words, the nerve root must be involved.

Using the same deductive method, a specific lumbar nerve root lesion can be diagnosed. To illustrate this, let us assume that the 1st sacral nerve root is compressed by a herniated nucleus pulposus. As in the case of the cervical nerve root lesion, a definite sequence of muscle testing is followed. The needle electrode is placed successively into several areas of the quadriceps femoris (L-2, L-3 and L-4) and no evidence of denervation is found. Progressing, the tibialis anticus (L-4 and L-5) is thoroughly sampled and, again, no denervation fibrillation voltages are picked up. However, in the extensor hallucis longus, extensor digitorum longus, and peroneus longus (L-5 and S-1) a considerable amount of denervation fibrillation voltages is demonstrated. Similarly, in the gastrocnemius (L-5, S-1 and S-2) and the soleus (S-1 and S-2) the EMG reveals evidences of denervation. Since we have demonstrated that the muscles supplied by the 4th and 5th lumbar nerve roots are not involved, whereas the muscles partially innervated by S-1 are, the lesion must be compressing this root. Finally, denervation is found in the erector spinae group which is segmentally innervated by the posterior primary divisions, thus proving that the root and not a portion of the lumbosacral plexus is implicated.

In our hands this method of localizing an isolated nerve root lesion has been used successfully in diagnosing involvement, from whatever cause, of the 6th, 7th and 8th cervical nerve roots and the 5th lumbar and 1st sacral nerve roots. Further work is being done to extend and perfect this method.

## THE NERVE PLEXUSES

Lesions of the *brachial plexus* need to be differentiated, most commonly, from those of the cervical nerve roots, or those of peripheral nerves. Pressure

on the brachial plexus, for instance, by the anterior scalene muscle or a cervical rib, is almost invariably accompanied by EMG evidence of diffuse denervation of the upper extremity, whereas a cervical nerve root lesion shows segmental denervation only in those muscles served by that specific root. Another point of differentiation is that in brachial plexus lesions the posterior primary divisions are never involved and, therefore, denervation fibrillation voltages are never found on the erector muscles of the neck such as are found in cervical nerve root lesions. For example, we all see the patient who complains of radiating pain down the arm. Neurologic examination may reveal neither the classical signs of an anterior scalene syndrome or those of a cervical disc. Here the EMG can rule out the cervical nerve root lesion by demonstrating, first, diffuse denervation of the arm and, second, absence of fibrillation voltages in the posterior neck muscles. This evidence is present in spite of the lack of specific reflex, motor or sensory findings on clinical examination. We hope, with further experience, to confirm the fact that brachial plexus lesions can be differentiated from those occurring in the axilla by finding denervation fibrillation voltages in the infraspinatus muscle (supplied by the subscapular nerve, which usually arises well above the axilla).

The *lumbosacral plexus* is involved by many conditions, either intra- or extrapelvically, without definite neurological signs differentiating the lesion from involvement of the spinal nerve roots. Again, the important EMG finding is diffuse denervation of the leg without segmental denervation of the erector spinae group. Lumbosacral plexus involvement can be distinguished from peripheral nerve injuries because in the former the denervation is usually found to be diffuse in the lower extremity whereas in the latter it is found only in the muscles supplied by the specific nerve. An important point in this respect is the differentiation of a pure lumbar plexus lesion from a femoral nerve injury, or a sacral plexus injury from a sciatic nerve injury. In both instances the plexus lesion produces denervation of the gluteus muscles which is absent in the peripheral nerve injuries.

## PERIPHERAL NERVE INJURIES

The electromyograph reaches its highest degree of accuracy in the diagnosis and prognosis of peripheral nerve injuries. A *completely severed peripheral nerve* will show, approximately 18 days after injury (in the human), denervation fibrillation voltages from all areas of the muscles tested. In addition, no discrete motor unit voltages are produced from any portions of the affected muscles by voluntary contractions. The only bio-electrical sign seen during such voluntary activity is a disturbance of the cathode ray base-line, which is a result of motor unit contractions arising from adjacent muscles not innervated by the same nerve, and with experience this can be clearly recognized. Thus, a confident opinion can be expressed by the electromyographer that complete interruption of the nerve exists.

Immediately, therefore, the neurosurgeon can reapproximate the severed

ends without undue delay. This is of paramount importance since there is an inverse relationship between a prolonged interval before suture and the effectiveness of the results.

After a nerve suture has been done, and following an appropriate waiting period for nerve regeneration to occur, beginning motor unit contractions are seen in the paralyzed muscles. The frequency and amplitude of the denervation fibrillation voltages gradually diminishes and the cathode ray baseline disturbance is replaced at first by complex (or polyphasic) motor unit contractions of very low amplitude and frequency and, finally, simple motor unit contractions begin to appear. These electromyographic phenomena can be seen long before clinical evidence of motion occurs and assures the surgeon that his nerve suture is intact and reinnervation is occurring.

Using a mean rate of 2.5 mm. a day for neurotization, and 1.7 mm. per day for maturation (complete myelinization) a table has been constructed which makes it possible to determine the approximate time interval before EMG evidence of regeneration appears. If, after this appropriate waiting period, which is markedly shorter than the usual period of clinical waiting, no EMG evidence of regeneration of the nerves is demonstrated, immediate reexploration should be carried out. Again the neurosurgeon is afforded the earliest opportunity to establish the continuity of the nerve and, thus, forestall further atrophy of the affected nerve pathways and muscles.

In *partial nerve injuries*, despite the clinical evidence of complete paralysis, the EMG enables the examiner, on finding motor unit contractions, to state that intact nerve fibers exist and, therefore, the chances of spontaneous regeneration are good. The importance of this to the neurosurgeon is obvious.

In *peripheral neuritis* the EMG reveals far more widespread denervation fibrillation than can be detected on neurologic examination. This is often of diagnostic value in ruling out purely localized lesions or "functional" states.

## CRANIAL NERVES

The most frequent use of the EMG in testing the motor function of cranial nerves is in lesions of the *facial nerve*. Of these, Bell's palsy is the most common. If, after three weeks (the time necessary for denervation fibrillation to commence in human muscle) denervation fibrillation voltages are found in all areas of the facial musculature and if, with voluntary effort, no discrete motor unit contraction waves occur, a diagnosis of complete interruption of the facial nerve may be made. Thus, if, after an appropriate waiting period, there is still no EMG evidence of return, the neurosurgeon can undertake early surgical intervention before irreversible changes have occurred in the muscle. Conversely, if voluntary motor unit voltages are elicited from any part of the affected muscles, no matter of how small amplitude, then, despite the clinical evidence of complete paralysis, it is possible to state that at least a portion of the nerve is still intact and to predict that spontaneous recovery should occur.

Another instance in which the electromyographic examination of the

facial muscles is of diagnostic importance is in differentiating compressive lesions of the high cervical cord (cord tumors, Arnold-Chiari deformity, etc.) from widespread degenerative disease of the nervous system. In the latter, subclinical denervation of the facial muscles can be demonstrated, whereas in the former none is found.

We hope, with further experience, to demonstrate the value of electromyography in other disorders of the cranial motor system. An example of this might be the testing of the lateral rectus muscle in traumatic lesions of the 6th nerve in order to determine whether or not the lateral rectus muscle is completely denervated so that the ophthalmological surgeon could proceed with surgical corrective measures before irreversible muscle changes could occur.

## PRIMARY DISORDERS OF THE MUSCULAR SYSTEM

The most dramatic and pathognomonic electromyographic picture is seen in the *myotonias*. When the needle electrode is inserted into the muscles of the patient suffering from *myotonia congenita* (Thomsen's disease), *myotonia dystrophica* (*atrophica*), and *myotonia acquisita* (Talma's disease), there is a tremendous burst of what are apparently spontaneous, involuntary, simple motor unit discharges. These wave forms are of high amplitude, rapid in frequency, and are accompanied by a high-pitched howling noise over the amplifier. Both the characteristic wave forms and sound from the hyperirritable muscle reach an immediate crescendo, then wax and wane to reach electrical silence within a few seconds. The slightest touch on the implanted needle electrode sets off an immediate repetition of this phenomenon. No denervation fibrillation voltages are seen, placing the myotonias in the category of a primary muscular disorder. Voluntary contraction produces normal diphasic wave forms which persist for a period after the patient attempts to relax the muscle.

In the *muscular dystrophies*, whether pseudo-hypertrophic, atrophic, or a combination of both, there is no evidence of lower motor neuron disease and no characteristic wave forms appear, such as are seen in the myotonias. However, with voluntary contraction, the amplitude and frequency of the normal diphasic wave forms are diminished as compared with those found in the normal skeletal muscle. With the EMG an early differential diagnosis between a pure muscular dystrophy and progressive muscular atrophy can be established.

Electrically, *myasthenia gravis* shows no evidence of lower motor neuron disease of the skeletal musculature. With voluntary contraction, however, as might be expected, there is a gradual diminution in the amplitude and frequency of the diphasic discharges progressing, in some instances, to a complete iso-electric base-line. After a period of rest, there is a gradual reappearance of normal contraction potentials.

Often a patient may be suspected, because of gross fascicular twitchings of the muscles of the extremities, of suffering from a degenerative disease of

the anterior horn cells such as amyotrophic lateral sclerosis. If these fasciculations are found to be, electromyographically, of a simple diphasic type, and if no denervation fibrillation voltages are seen, a *myokymia* may be suspected and the more serious disorder ruled out.

## MEDICOLEGAL ASPECTS OF ELECTROMYOGRAPHY

The EMG assumes an important position in forensic medicine, because it offers indisputable and objective evidence of the presence or absence of lower motor neuron disease. This evidence has already been accepted as bona fide in some courts. The particular value of the EMG lies in its ability to determine more accurately than purely clinical examinations whether or not the patient is suffering from an organic disease of the lower motor neuron system. In addition, the disease process can be accurately localized in many cases, so that in the psychoneurotic or malingerer a true evaluation can be reached. With the myoscopic tape record it is possible for the physician to have in his possession a reproducible permanent record of the patient's original condition and subsequent course. Evidence of this nature is of great legal importance in this era of the litigious-minded patient.

## SOURCES OF ERROR IN ELECTROMYOGRAPHY

Electromyography, depending upon a mechanical diagnostic instrument, is subject to errors arising, first, from lack of skill or thoroughness on the part of the examiner; second, from incorrect interpretation of the electromyogram; and third, from the fact that there are anatomic variations of motor nerve supply just as are seen in the sensory distribution.

As we have previously emphasized, the technique of multiple electrode insertions and extensive sampling of the skeletal muscles must invariably be carried out. There is often a tendency on the part of the electromyographer to limit his efforts because of the discomfort to the patient, thus failing to discover significant evidences of lower motor neuron disease.

Considerable experience is required on the part of the electromyographer in interpreting certain aberrant wave forms which may arise at the time of insertion or motion of the needle electrodes, from outside electrical interference, or from the normal contraction potentials of certain small muscles such as those of the face, which may be confused with denervation fibrillation voltages.

A major source of confusion arises in surveying certain patients who demonstrate widespread lower motor neuron disease in spite of the fact that they clinically have only a localized lesion. We feel that these patients may have suffered in the past from some unrecognized disease of the nervous system such as subclinical poliomyelitis, and thus retain evidences of lower motor neuron disease. In older patients this confusion also arises occasionally because of circulatory insufficiency which results in damage to the anterior horn cells. In these cases the electromyographer must utilize his clinical knowledge in interpreting the EMG findings.

Finally, it should be re-emphasized that there must be an approximate waiting period of 18 days after interruption of the nerve supply to a human skeletal muscle before denervation fibrillation voltages appear and any accurate conclusions can be reached.

## CONCLUSIONS

1. The electromyograph, utilizing a monopolar needle electrode, cathode ray oscilloscope, sensitive sound amplifier, and a magnetic tape recorder, is a diagnostic instrument with a high degree of accuracy in diagnosing certain diseases of the neuromuscular system.

2. In diseases of the spinal cord affecting the anterior horn cells, the EMG offers early diagnostic and prognostic information that often cannot be obtained by any other means.

3. The differential diagnosis between certain spinal cord tumors (i.e. high cervical) and degenerative spinal cord disease is often established by electromyography.

4. Specific spinal nerve root involvement can be diagnosed accurately with the EMG and differentiated from plexus or peripheral nerve lesions.

5. In peripheral nerve lesions the EMG is of great value in determining (a) the presence of complete or partial interruption; (b) the earliest possible evidences of reinnervation following nerve suture; (c) the shortest period of delay before re-exploration can be carried out if no evidences of reinnervation have occurred.

6. The EMG can accurately separate the diseases of the anterior horn cells of the spinal cord from those affecting the skeletal musculature alone.

7. Medicolegally the EMG is of great importance because the finding of denervation fibrillation voltages is indisputable objective evidence of the presence of lower motor neuron disease.

8. The accuracy of electromyography depends first on knowledge of neuromyology; second, on proper techniques of examination; and third, on recognition of fundamental sources of error.

9. The improved clinical electromyograph is opening up new investigative fields in the physiology and pathology of the nervous and muscular systems.

## REFERENCES

1. Bauwens, P. Electromyography in clinical medicine. *Brit. J. phys. Med.*, 1947, n.s. *10:* 75–78.
2. Bauwens, P. Electromyography. *Brit. J. phys. Med.*, 1948, n.s. *11:* 130–136.
3. Bowden, R. E. M. The value of electromyography in lesions involving the lower motor neurone. *Proc. roy. Soc. Med.*, 1946, *39:* 339–341.
4. Brazier, M. A. B., Watkins, A. L., and Michelsen, J. J. Electromyography in differential diagnosis of ruptured cervical disk. *Arch. Neurol. Psychiat., Chicago*, 1946, *56:* 651–658.
5. Brazier, M. A. B., Watkins, A. L., and Schwab, R. S. Electromyographic studies of muscle dysfunction in infectious polyneuritis and poliomyelitis. *New Engl. J. Med.*, 1944, *230:* 185–189.
6. Cuthbert, N. L., and Denslow, J. S. Electrode efficiency and subject positioning in electromyography. *Proc. Soc. exp. Biol., N. Y.*, 1945, *58:* 191–193.
7. Denny-Brown, D. Interpretation of the electromyogram. *Arch. Neurol. Psychiat., Chicago*, 1949, *61:* 99–128.

8. Denny-Brown, D., and Pennybacker, J. B. Fibrillation and fasciculation in voluntary muscle. *Brain*, 1938, *61:* 311–334.
9. Feinstein, B., Pattle, R. E., and Weddell, G. Metabolic factors affecting fibrillation in denervated muscle. *J. Neurol. Neurosurg. Psychiat.*, 1945, n.s. *8:* 1–11.
10. Golseth, J. G. The medical-legal aspects of electromyography. (In press)
11. Golseth, J. G., and Fizzell, J. A. Electromyographic studies on cats after section and suture of the sciatic nerve. *Amer. J. Physiol.*, 1947, *150:* 558–567.
12. Golseth, J. G., and Huddleston, O. L. Electromyographic diagnosis of lower motor neuron disease. *Arch. phys. Med.*, 1949, *30:* 495–499.
13. Hirschberg, G. G., and Abramson, A. S. Clinical electromyography. Physiologic basis, instrumentation, diagnostic value. *Arch. phys. Med.*, 1950, *31:* 576–587.
14. Hoefer, P. F. A., and Guttman, S. A. Electromyography as a method for determination of level of lesions in the spinal cord. *Arch. Neurol. Psychiat., Chicago*, 1944, *51:* 415–422.
15. Hoefer, P. F. A., and Putnam, T. J. Electromyographic studies of normal and abnormal movement. *Trans. Amer. neurol. Ass.*, 1939, 18–23.
16. Huddleston, O. L., and Golseth, J. G. Electromyographic studies of paralyzed and paretic muscles in anterior poliomyelitis. *Arch. phys. Med.*, 1948, *29:* 92–98.
17. Huddleston, O. L., Golseth, J. G., Marinacci, A. A., and Austin, E. The use of electromyography in the diagnosis of neuromuscular disorders. *Arch. phys. Med.*, 1950, *31:* 378–387.
18. Jasper, H. H., and Johnston, R. H. A portable clinical electromyograph. Report to Associate Committee on Army Medical Research, National Research Council, Canada, from the Montreal Neurological Institute, McGill University, 1945.
19. Kohn, P. M., Zucker, E. M., and Toomey, J. A. Electromyographic studies in poliomyelitis. *J. nerv. ment. Dis.*, 1945, *102:* 433–439.
20. Lindsley, D. B. Electromyographic studies of neuromuscular disorders. *Arch. Neurol. Psychiat., Chicago*, 1936, *36:* 128–157.
21. Loofbourrow, G. N. Electrographic evaluation of mechanical response in mammalian skeletal muscle in different conditions. *J. Neurophysiol.*, 1948, *11:* 153–167.
22. Shea, P. A., Woods, W. W., and Werden, D. H. Electromyography in diagnosis of nerve root compression syndrome. *Arch. Neurol. Psychiat., Chicago*, 1950, *64:* 93–104.
23. Watkins, A. L. Electromyographic studies in poliomyelitis. *J.-Lancet.*, 1944, n.s. *64:* 233–236.
24. Watkins, A. L. Physical medicine and neurology. *Clinics*, 1946, *4:* 1486–1515.
25. Weddell, G. Electromyography. *Med. Times, N. Y.*, 1945, *73:* 37–39.
26. Weddell, G. Observations on the value of electromyography in lesions involving the lower motor neurone in man. *Proc. roy. Soc. Med.*, 1946, *39:* 339.
27. Weddell, G., Feinstein, B., and Pattle, R. E. The clinical application of electromyography. *Lancet*, 1943, *1:* 236–239.
28. Weddell, G., Feinstein, B., and Pattle, R. E. The electrical activity of voluntary muscle in man under normal and pathological conditions. *Brain*, 1944, *67:* 178–257.

# THE USE OF GELFOAM FILM AS A DURAL SUBSTITUTE

## PRELIMINARY REPORT

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For many years attempts have been made to find a dural substitute that would prevent or lessen the formation of meningocerebral adhesions, because it is thought that the scar tissue developing between the dura and the brain in cerebral wounds is an important factor in producing headache, convulsions and other sequellae.

Various materials have been used. Autogenous fascial transplants have been found to cause a dense fibrous scar.[11] Human amniotic membrane, amnioplastin, beef allantoic membrane, Cargile membrane, tantalum foil and polyvinyl alcohol film are likewise unsuitable as a dural substitute according to Pudenz and Odom.[12] Other metal foils, cellophane and rubber tissue have been used with varying results.[5,13]

Since the introduction of absorbable gelatin foam and fibrin products, there has been developed an absorbable fibrin film. This preparation has been used extensively by Ingraham and Bailey.[1,7,8] They report that fibrin film is easy to handle, translucent, flexible, absorbs in about 40 days[10] and prevents adhesions from developing between the dura and the brain. The chief objections to it are its cost, the fact that it requires special storage and handling and that it cannot be resterilized easily. Otherwise it is an ideal dural substitute.

Recently polythene film has been used as a dural substitute and has been shown by Brown, Grindlay and Craig[2,3] and by Ingraham, Alexander and Matson[6] to prevent adhesions between the dura and the brain. It overcomes many of the objections to fibrin film but is a nonabsorbable material and causes the formation of a thin, nonadherent neomembrane beneath it. Because of this latter reaction, it is conceivable that over a long period of time an envelope may form similar to that which develops about tantalum foil. Should this be true, the same objections would hold as for other foreign material.

The purpose of this report is to present experimental and some clinical evidence for a new material, gelfoam film,* which we believe fulfills all the requirements of an ideal dural substitute. This gelatin film is supplied steri-

* The gelatin film was supplied by the Upjohn Company, Kalamazoo, Michigan, under the trade name "Gelfoam Film."

lized in a sealed paper envelope, 4×5 inches in size. It is slightly thicker than cellophane, transparent and can be cut to shape easily but will crack if handled roughly. When moistened, its consistency becomes rubbery and thus molds to contours but tears easily. If care is exercised, it can be sutured loosely to the dura. It can be resterilized in dry heat at 140°C. for 4 hours.[4] No special storage or handling is necessary and the cost is low.

## METHOD OF STUDY

Two large (20 kg.) dogs were used to determine the reaction of the dura and cerebral cortex to the gelfoam film. The operative procedure was performed in the following manner:

The scalp was shaved and prepared with iodine and alcohol with the dog under amytal anesthesia. A curved incision was made in the scalp and reflected laterally, exposing the temporal muscle. The latter was cut from its periosteal attachment to the skull and reflected temporally. The exposed bone was rongeured away creating a defect about 4×4 cm. All of the presenting dura was excised carefully. A piece of gelfoam film was cut to the size of the defect, moistened and applied to the surface of the brain, tucking the edges beneath the dura all about the wound. The temporal muscle was replaced and sutured to its periosteal attachment by interrupted cotton sutures. The scalp was closed by interrupted cotton sutures.

On the opposite side of the skull, the same procedure was followed except that the cortex was traumatized by puncturing it with a large needle over the entire exposed area.

In the first dog the operations were spaced 13 days apart and the animal was sacrificed on the 28th day, so that the wounds were 15 and 28 days old. In the second dog the operations were separated by 30 days and the animal was sacrificed on the 70th day, so that the wounds were 40 and 70 days old. Thus the wounds with the intact cortex were 28 and 70 days old and those with the traumatized brain 15 and 40 days old.

The animals during the observation period showed no evidence of cortical irritation.

Immediately after the animal was sacrificed, the heads were removed and prepared after the technique of Ingraham and Bailey.[7]

## RESULTS

The gelfoam film was found to be intact in the first animal with wounds 15 and 28 days old. It was encased in an envelope, more evident in the older wound, of connective tissue. This envelope extended from the edges of the intact dura. The outer layer was thicker than the inner layer and was adherent to the temporal muscle, although easily separated from it. The inner layer was separated from the cortex, forming a clear space without evidence of adhesions, both grossly and microscopically, between it and the cortex. This was likewise true in the 15-day-old preparation where the cortex had been traumatized.

The gelfoam film had partially disappeared in the 40-day and almost

completely in the 70-day-old wound (Fig. 1). Its presence was in the form of isolated fragments. The fibrous-tissue envelope in the areas where no film was present maintained a separation between the outer and inner layers. The inner layer was continuous with the intact dura, making it impossible to determine the point of regeneration. There were no adhesions between the newly formed dura and the cortex either in the intact cortex (70 days postoperative) or in the traumatized cortex (40 days postoperative) preparations.

The microscopic appearance in all four preparations showed very little

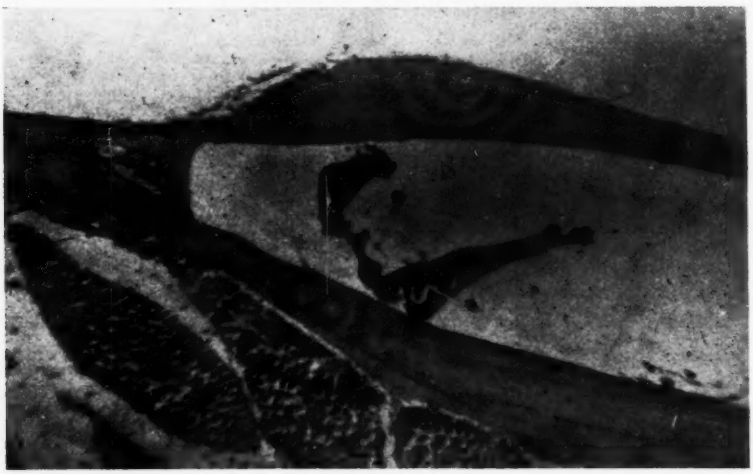

FIG. 1. The point of junction of normal dura and the newly formed envelope in the 70-day wound. The gelfoam film is beginning to fragment. The fibrous envelope can be seen to originate from the inner layer of the dura and the temporal muscle. The inner layer of the envelope is almost similar in size and composition to the surrounding normal dura. No adhesions appear between the brain and newly formed dura.

cellular reaction in the tissues. Polymorphonuclear leukocytes were uncommon, whereas large mononuclear cells and lymphocytes were more abundant in the neomembranes. No giant cells were seen. The neomembranes appeared to originate from the dura and the temporal muscle. In the 15- and 28-day-old preparations, where the gelfoam film was intact, there was only slight evidence of tissue infiltration. In the 70-day-old preparation the inner neomembrane appeared as normal dura.

## CLINICAL DATA

Gelfoam film has been used clinically in a number of patients in whom the dura was removed for various reasons. In 2 patients who died at 6 and 8 days respectively, autopsy revealed that the film was the same rubbery consistency as it was when introduced into the wound and the tissue reaction was no more than would be expected following an operative procedure.

In other patients with craniotomies for various reasons in whom the film

had been introduced at operation, it was possible to make observations up to 3 months postoperatively. In those patients reoperated upon within a 30-day period, the gelfoam film was found intact; between 30 and 40 days it had become fragmented and after 90 days, it was either completely absorbed or only a few small fragments remained.

It was obviously more difficult to make observations on the neomembrane formation in human subjects as compared to our animal experiments, but it was felt that a fine connective-tissue envelope began to form about the film in 7 days. At 2 months the envelope could be definitely seen and was continuous with the dura all about the defect. This neomembrane stripped from the underlying brain readily and without evidence of adhesions. Where the raw surface of brain or a tumor cavity was covered by the neomembrane, there was a "stickiness" that suggested the possibility of adhesions forming. The character of this adhesiveness of the neomembrane to the raw brain or tumor bed did not seem to have the intensity that would cause a pathological effect upon the cortex.

The gelfoam film has been used in 24 patients at the present time without evidence of infection except in 1 patient. In this instance a brain abscess developed in the operative site 1 month following the removal of a large, necrotic occipital lobe glioblastoma multiforme tumor. At re-operation the abscess was drained and as much of the remaining tumor removed as was possible. The same piece of gelfoam film that had been used at the first operation was replaced over the tumor cavity. The wound was drained for 2 days and healed per primam.

## COMMENT

In 1923 Sayad and Harvey[14] published a paper discussing the subject of regeneration of the dura mater. They found that the dura rapidly regenerates in from 1 to 2 weeks. If the endothelial covering of the arachnoid is kept intact, the dura will regenerate and fill in its own defect without adhesions. If the endothelial lining of the arachnoid is destroyed or damaged, then the dura as it regenerates will become firmly attached to the adjacent layer of the arachnoid and pia by connective tissue.

The mechanism for repair of the dura is the same as for the repair of any tissue elsewhere in the body with the exception that the external surface of the arachnoid acts as a limiting membrane beyond which no further reaction takes place and against which the inner lining of the dura is formed. This impregnability of the arachnoid surface to the reaction of repair in the dura prevents the formation of adhesions and acts as a mold for the reconstruction of the dura. Lear and Harvey[9] later described the regeneration of the pia-arachnoid and they found that the essential point in the formation of adhesions is the injury to the outer cells of the arachnoid. The living cells of the pia-arachnoid are more highly differentiated than those of the dura and therefore more stable. The living cells (inner surface) of the dura are flattened polygonal mesothelial cells derived from the mesenchyme and when destroyed they are replaced by the transformation of mesenchymal elements

into mesothelium. They are less stable and readily enter into any adjacent inflammatory reaction. The inner surface of the dura, therefore, does not act as a limiting membrane in the presence of an attempted repair in the underlying meninges, but enters intimately into the process and heals with adhesions.

The purpose of the gelfoam film is to present a barrier to the living mesothelial cells of the dura at the dura-arachnoid junction, because the outer cellular layer of the arachnoid is obviously injured at operation. Since our experiments have shown that it takes at least 70 days for the film to absorb, more than sufficient time is given for the cells of the arachnoid to regenerate and thus set up a natural barrier to the formation of adhesions.

From the foregoing experimental and clinical data, it has been shown that gelfoam film is an effective dural substitute. It prevents adhesions from developing between the dura and cortex with practically no tissue reaction. The fact that the film is absorbed in about 80 to 90 days overcomes the disadvantage to all foreign material. The ease of handling and its low cost permits a wide use as compared to fibrin film, yet it has all the advantages of the latter.

## REFERENCES


1. Bailey, O. T., Ingraham, F. D., Neuhauser, E. B. D., and Cobb, C. A., Jr. Fibrin film in neurosurgery, further studies. The insertion of fibrin film between the sutured dura and the intact leptomeninges; the effect of roentgen therapy on tissue reactions to fibrin film. *J. Neurosurg.*, 1947, *4:* 465–471.
2. Brown, M. H., Grindlay, J. H., and Craig, W. McK. The use of polythene film as a dural substitute. A preliminary report. *J. Neurosurg.*, 1947, *4:* 505–507.
3. Brown, M. H., Grindlay, J. H., and Craig, W. McK. The use of polythene film as a dural substitute. An experimental and clinical study. *Surg. Gynec. Obstet.*, 1948, *86:* 663–668.
4. Correll, J. T., and Vanderpoel, J. C. Biologic absorption of insolubilized gelatin films. *Proc. Soc. exp. Biol., N. Y.*, 1949, *71:* 134–136.
5. Delarue, N. C., Linell, E. A., and McKenzie, K. G. An experimental study on the use of tantalum in the sub-dural space. *J. Neurosurg.*, 1944, *1:* 239–242.
6. Ingraham, F. D., Alexander, E., Jr., and Matson, D. D. Polyethylene, a new synthetic plastic for use in surgery. Experimental applications in neurosurgery. *J. Amer. med. Ass.*, 1947, *135:* 82–87.
7. Ingraham, F. D., and Bailey, O. T. The use of products prepared from human fibrinogen and human thrombin in neurosurgery. Fibrin foams as hemostatic agents; fibrin films in repair of dural defects and in prevention of meningocerebral adhesions. *J. Neurosurg.*, 1944, *1:* 23–39.
8. Ingraham, F. D., Bailey, O. T., and Cobb, C. A., Jr. The use of fibrin film as a dural substitute and in the prevention of meningocerebral adhesions. Further studies and clinical results. *J. Amer. med. Ass.*, 1945, *128:* 1088–1091.
9. Lear, M., and Harvey, S. C. The regeneration of the meninges. The pia-arachnoid. *Ann. Surg.*, 1924, *80:* 536–544.
10. Morrison, P. R., and Singer, M. Chemical, clinical, and immunological studies on the products of human plasma fractionation. XVII. A note on the absorption rates of fibrin films in tissue. *J clin. Invest.*, 1944, *23:* 573–575.
11. Neuhof, H. The treatment of craniocerebral wounds and its results. *Ann. Surg.*, 1920, *72:* 556–588.
12. Pudenz, R. H., and Odom, G. L. Meningocerebral adhesions. An experimental study of the effect of human amniotic membrane, amnioplastin, beef allantoic membrane, Cargile membrane, tantalum foil, and polyvinyl alcohol films. *Surgery*, 1942, *12:* 318–344.
13. Robertson, R. C. L., and Peacher, W. G. The use of tantalum foil in the subdural space. *J. Neurosurg.*, 1945, *2:* 281–284.
14. Sayad, W. Y., and Harvey, S. C. The regeneration of the meninges. The dura mater. *Ann. Surg.*, 1923, *77:* 129–141.

# SERIAL ELECTROENCEPHALOGRAPHY IN ACUTE HEAD INJURIES*

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THERE are several reports of the electroencephalographic findings in acute head injuries in man.[2–7,10–12,14,15,17] None of these are serial studies. Serial EEG studies were therefore undertaken in order to determine the sequence of EEG changes from the acute phase through to death or recovery, and also to ascertain how reliable an isolated examination may be in evaluating the over-all damage and the presence of complications.

Serial EEGs were obtained in 45 patients with acute head injuries. The degree of injury varied from a mild concussion to an injury that proved fatal in 2 hours. The final diagnoses are shown in Table. 1. The age range was from 2 years to 90 years, with 4 children, 2 in their teens and the rest adults. The first examination was made as soon as the patient could be transported from the emergency room or as soon after admission as his condition permitted. The initial examination was made within 12 hours of injury in 51 per cent, within 48 hours in another 24 per cent and the remainder within 5 days.

TABLE 1

*Final diagnosis*

| | Cases | Deaths |
|---|---|---|
| Concussion | 15 | 0 |
| Contusion | 5 | 0 |
| Depressed fracture and lacerated brain | 3 | 0 |
| Gunshot | 2 | 2 |
| Intracranial hematoma and hygroma | 17 | 11 |
| Exact diagnosis not established | 3 | 3 |
| Total | 45 | 16 |

A total of 210 records were obtained, or an average of 5 per case. Within 3 days of injury, 11 patients died and 8 patients recovered. These 19 patients had an average of 3 tracings each. The remaining 26 had an average of 6 tracings per patient with a maximum of 13 EEGs in a single case. A few patients of special interest are included who, because of their rapid or critical course, had only 1 or 2 tracings.

The material is weighted with the more seriously injured patients because only those requiring hospitalization and for whom neurosurgical consulta-

* Aided by the Kresge Fund.

tion had been requested were selected for study. Sixteen patients, or 36 per cent of the series, died as a result of their injuries. Eleven of these died within 3 days of injury and the other 5 within 6 weeks of injury. The pathology as observed at autopsy or operation is shown in Table 2.

TABLE 2

*Deaths*

*16 deaths—36 per cent of series*

| | Cases | Died within 72 Hours | Operated |
|---|---|---|---|
| Acute subdural hematoma | 6 | 5 | 2 |
| Intracerebral hematoma | 3 | 2 | 1 |
| Gunshot wound | 2 | 1 | 1 |
| Epidural hematoma | 1 | — | 1 |
| Subdural hygroma | 1 | — | 1 |
| Not established | 3 | 3 | 1 |
| | 16 | 11 (69%) | 7 (44%) |

Forty-three patients had roentgenograms of the skull. There were fractures in 29 (67 per cent). Twenty-three had linear fractures. Six had compound fractures including 3 with depressed bone and laceration of brain. There were 2 with gunshot wounds and there was 1 patient with a knife blade imbedded in the brain. These cases are shown in Table 3, along with the mortality.

TABLE 3

*Fractures*

*43 patients x-rayed—29 had fractures (67 per cent)*

| | Cases | Deaths |
|---|---|---|
| (A) Fractures present | | |
| 1. Linear | 23 | 7 |
| 2. Depressed | 3 | 0 |
| 3. Gunshot | 2 | 2 |
| 4. Knife blade | 1 | 0 |
| (B) No fractures present | 14 | 5 |
| Total | 43 | 14 |

Intracranial lesions diagnosed at operation, autopsy or both included contusions, lacerations and hematomas or hydromas. They occurred in 22 cases (49 per cent of the series, Table 1). Of the patients with linear fractures, 65 per cent had such lesions, whereas only 44 per cent of the patients without fractures had similar findings. Correlation of fracture site and site of intracranial complications revealed that the lesion was opposite to the fracture site in about two-thirds of these cases. This was not true of the epidural hematomas.

## METHOD

An 8-channel Grass recording apparatus was used. Six pairs of leads were placed routinely in the frontal, premotor, motor and occipital areas and on the ear lobes. Silver disc electrodes were secured to the scalp by means of bentomite paste and a 1-inch square of adhesive tape. After obtaining a short sample of ear-to-ear activity, about 5 minutes of scalp-to-ear and another 5 minutes of scalp-to-scalp recording was obtained at each sitting. If the patient was restless, it was generally possible to bide our time until at least a short sample was obtained free of artifact. The entire procedure consumed from 30 to 40 minutes a record.

In most cases, the scalp-to-ear and the scalp-to-scalp recordings were in agreement. Any irreconcilable differences between the two were checked when possible or considered unreliable. In a few patients with focal suppressions, the focus was evident only on the scalp-to-scalp record. This was particularly true in patients with acute subdural hematoma. The same applied to focal delta activity, but to a much less extent.

## ANALYSIS OF RECORDS

In the analysis of the tracings the basic activity was evaluated first. The basic activity was found to fall into either normal, fast, slow or disorganized type of pattern. Other findings could be grouped into one of the following categories: (1) Focal suppression; (2) general suppression; (3) focal delta, or (4) epileptiform activity.

Various combinations of basic activity and other abnormalities occurred and the findings changed continually until the patient either recovered or died. Therefore, the different categories of changes are evaluated individually from the standpoint of incidence, degree, time of appearance and disappearance, and correlated with the clinical state or known pathologic lesions.

### BASIC RHYTHM

*Normal Basic Rhythm.* Nine patients had normal basic activity on the initial examination. All had focal abnormalities. Two of these had inversion of the alpha distribution, this being stronger in the frontal than in the occipital areas (Fig. 1). Both recovered. One of them had a subacute subdural hematoma. Four were comatose or semicomatose when the initial normal basic activity was recorded. The basic rhythm subsequently deteriorated in all of these and 2 of them died. The other 3 patients had mild injuries and recovered quickly with no deterioration in the basic rhythm. One of them had a subacute epidural hematoma in the temporal area and this was reflected in the EEG only by a voltage suppression of 50 per cent over the lesion.

It is evident in Fig. 1 that there is a definite lag in the deterioration of the EEG and that deterioration continues or remains for a time while the clinical state is improving. In others, the EEG is deteriorated from the start and improves with the clinical state. These two different responses may occur in patients with apparently similar injuries.

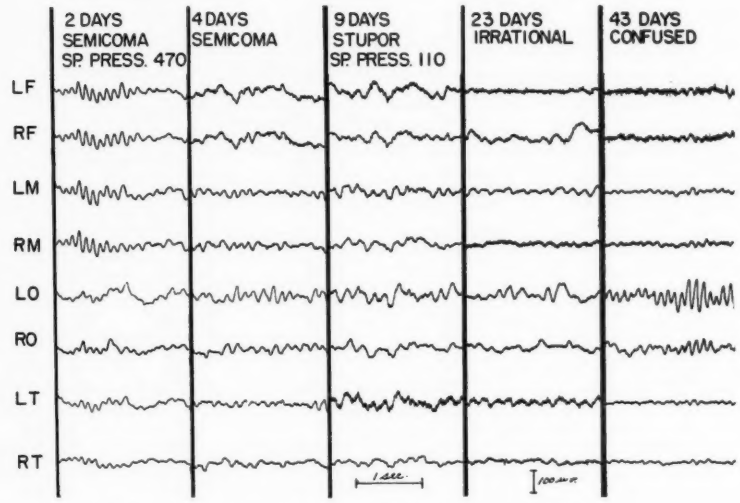


FIG. 1. J.K., male, aged 29. Auto accident. Unconscious 24 hours. Bilateral parietotemporal fracture. Arteriogram negative.

*Fast Basic Rhythm.* In 4 patients, the basic activity consisted of nearly continuous low voltage 12 to 15 per sec. waves. Only 1 of these patients survived. He was stuporous when the initial EEG was obtained 12 hours after injury. At 48 hours, he had recovered except for headache and had a normal alpha pattern at 9 to 10 per sec. (Fig. 2). Two others had acute

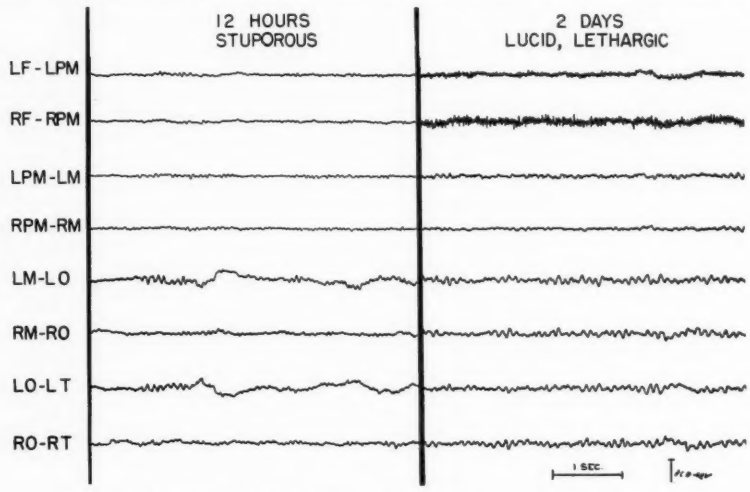


FIG. 2. F.I., male, aged 61. Beaten and robbed. Stuporous 18 hours. Fracture right temporal and base; pneumocephalus. Uneventful recovery.

subdural hematomas. Their initial EEGs were obtained after surgical evacuation of the hematoma and they expired without adequate follow-up studies. The remaining patient expired 4 days after injury from diffuse brain damage. He showed the same basic fast pattern on 3 occasions, the latest one being 12 hours before he expired.

*Slow Basic Rhythm.* Twenty-two patients had slow basic activity initially. The slow activity was disorganized in most of them but in a few the wave form and frequency were regular. Eight of these patients had

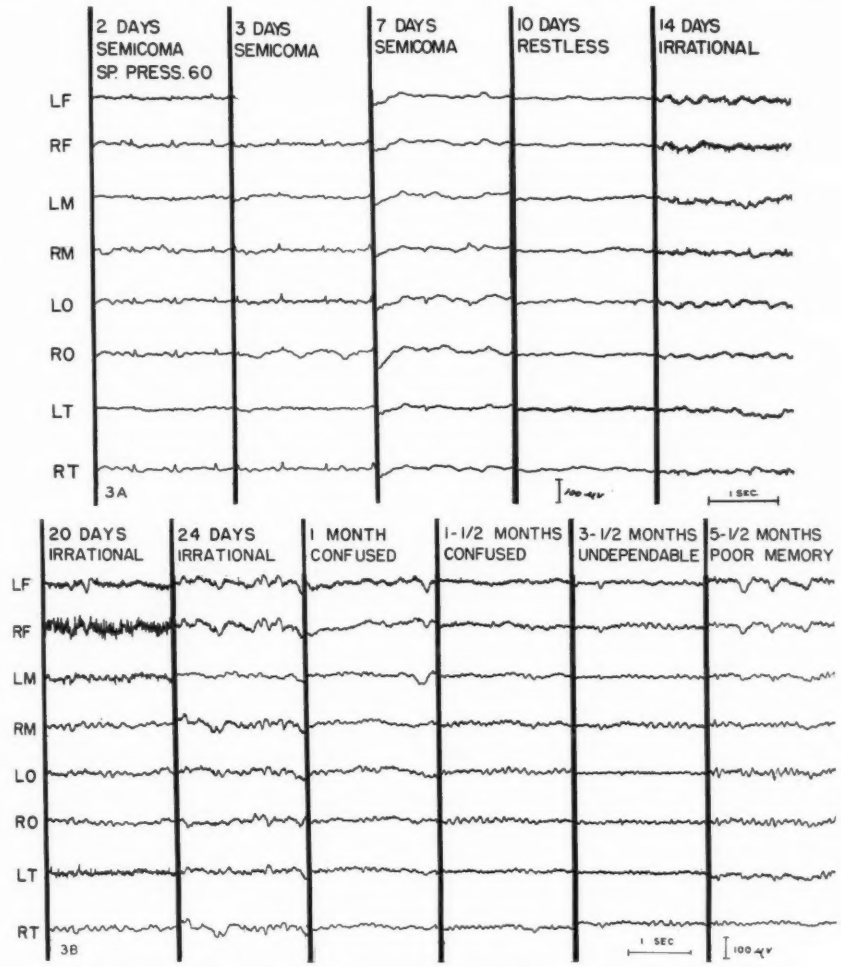


FIG. 3A, B. H.B., male, aged 55. Assaulted. Unconscious 12 hours. Fractures right frontoparietal and base. Slow but uneventful and incomplete recovery.

mild injuries. Their basic frequency ranged from 7 to 8 per sec. and returned to normal in a few hours or days. Five patients had severe and 9 had lethal injuries. The severe injuries initially showed only mild slowing, but progressive slowing ensued and became maximal 4 to 20 days after injury. In effect, the EEG showed a distinct lag before it slowed to a degree commensurate with the clinical picture and it continued to slow or remained slow for a time when the clinical state progressively improved (Fig. 3 A and B). The patients with lethal injuries showed a slow basic frequency of from 4 to 6 per sec. at the outset or slowed to this level within 48 hours (Fig. 4).

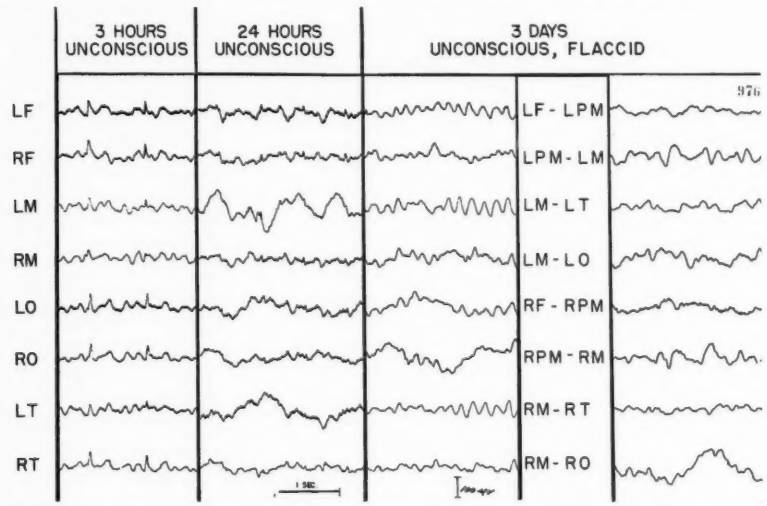


FIG. 4. J.D., male, aged 60. Slugged and robbed. Unconscious until death 5 days after injury. No operation. Fracture base, left. Autopsy: Multiple intracerebral hemorrhages; small subdural, right; laceration, right frontal.

If the initial basic frequency was between 4 to 6 per sec. or descended to this level within 48 hours, it was a grave sign. There were 6 such examples and these patients all died.

No patient was seen with a basic frequency below 4 per sec. If the basic rhythm fell to this frequency, practically all activity ceased. Complete suppression appearing within 30 hours after injury is also a grave sign. Three patients showed this finding and they all died (Fig. 5). Extreme slowing of the basic rhythm may be delayed and may appear from 3 to 10 days after injury, but under this circumstance it is not a grave sign and patients may actually show day-to-day improvement with such EEG findings (Figs. 1 and 3).

*Disorganized Basic Rhythm.* Ten patients had general or focal disorganization of the basic rhythm. The frequency of the rhythm was within normal range or only slightly slowed. Irregular amplitude was prominent in the

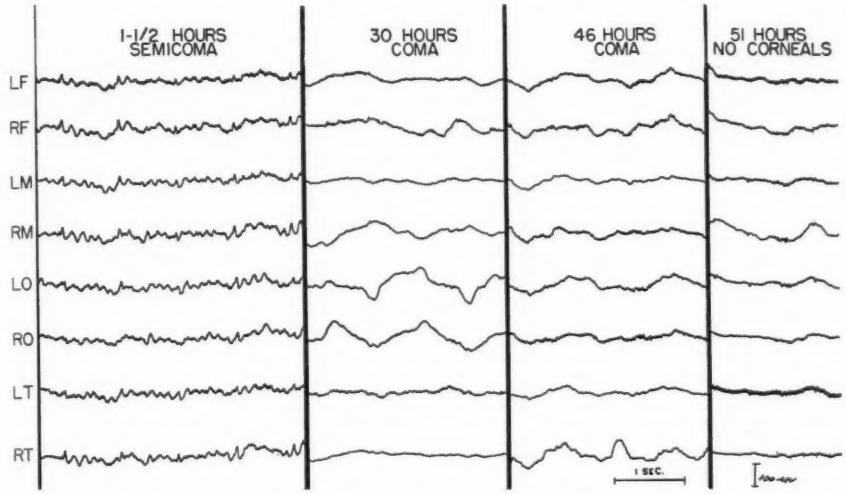


FIG. 5. F.J., male, aged 70. Walked into auto. Coma until death 71 hours after injury. Fracture right temporal and base. Arteriogram on left negative. Autopsy: Thin subdural hematoma, right; intratemporal lobe hemorrhage, right; small area softening, left frontal lobe.

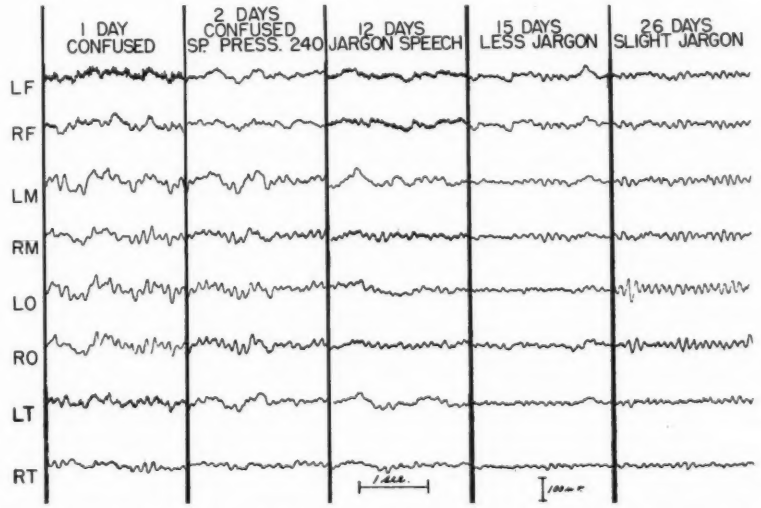


FIG. 6. J.R., male, aged 50. Hit by streetcar. Unconscious 1 hour. Fracture, left temporal. Trephine revealed contusion left motor-temporal area. Slight residual expressive aphasia when last seen 6 weeks after injury.

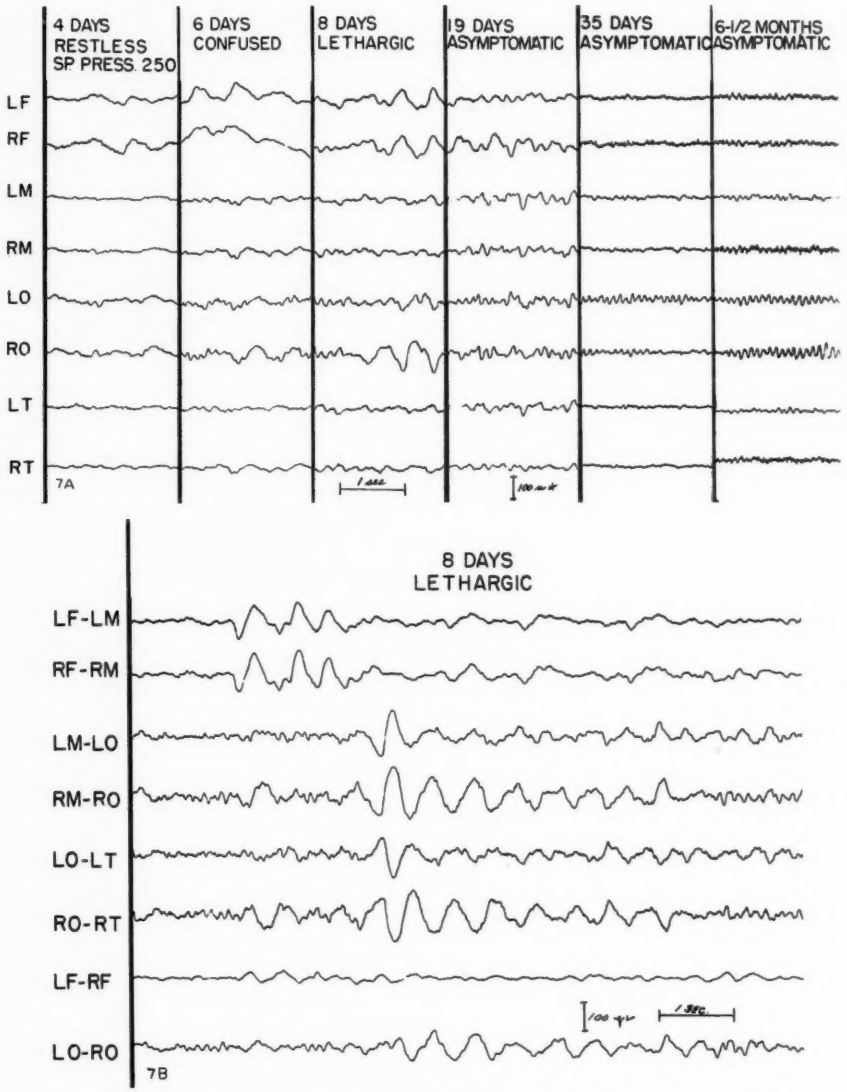


FIG. 7A, B. R.F., male, aged 17. Bicycle-car collision. Unconscious 2 hours. Depressed fracture left frontal; debrided, dura not torn. Uneventful recovery.

area of disorganization. Disorganization was present at the outset. It persisted for from 3½ hours to 28 days. It usually disappeared before the clinical state cleared (Fig. 6), but occasionally continued after the patient became

asymptomatic (Fig. 7A). It occurred only in mild or moderately injured patients. In 3 of the 10 cases the disorganization was focal. Two of these patients had contusions manifested by neurological deficit and the other had a knife blade imbedded in the anterior temporal lobe. The focus of disorganization and the area of damaged brain correlated in each instance.

### FOCAL SUPPRESSION

Focal suppression occurred in 33 cases. Generally, there was only a voltage suppression of 50 to 80 per cent, but in a fourth of the cases, focal suppression and irregular slow waves were combined. In all but 3 cases, the focal suppression was present on the initial examination or within 48 hours. In the others, it appeared from 3 to 9 days after injury. These delayed suppressions involved an entire hemisphere rather than a portion of a hemisphere.

Focal suppression cleared in the adults as a rule shortly before or by the time of clinical recovery. In children, the suppression persisted after clinical recovery and in 1 instance it continued for 4 months. If a focal suppression lasted for several days, the entire hemisphere generally became involved and in 8 cases both hemispheres were involved. Shifting focal suppressions were present in 3 patients with prolonged disability and a focus of suppression dropped out but recurred in 2 cases.

Of the 33 patients with this finding, 13 had no focal macroscopic lesion for correlation. Nine had focal contusions, destruction of brain or intracerebral hemorrhages and the suppression was over or in the vicinity of the lesion in all but one. The other 11 had subdural or epidural collections. The

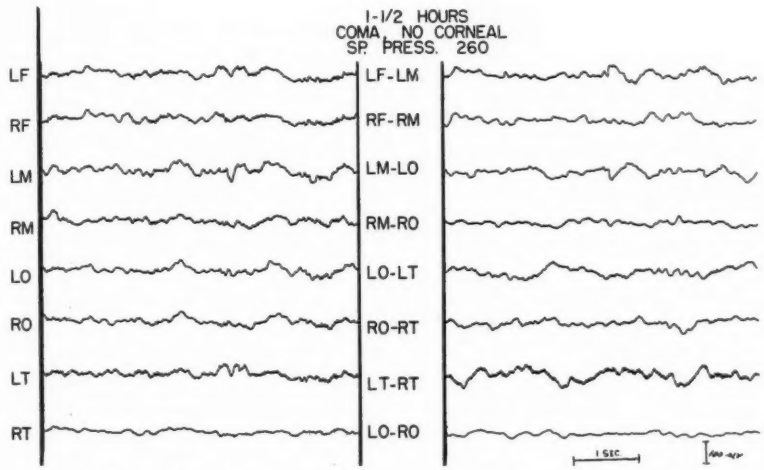


FIG. 8. R.H., male, aged 48. Hit-run accident. Coma until death 2 hours after injury. No fracture. Autopsy: Massive subdural hematoma on left.

suppression was located over the lesion in every case. However, in 2 cases of bilateral subdural collections, unilateral suppression occurred.

In acute subdural hematoma, there were no convincing suppressions over the lesion during the first 24 hours after injury. One might suspect that this was because the hematoma had not formed, but in the case presented in Fig. 8, the patient expired 30 minutes after the EEG had been obtained and a massive subdural hematoma was found over the left hemisphere. During the second or third day after injury, patients with acute subdural hematomas always showed suppression at least in the scalp-to-scalp recording over the lesion. In this study, none of the patients with acute subdural hematoma survived so it is not known whether the suppression persists, but in the 2 cases of subacute subdural hematoma the suppression persisted until after the lesions were evacuated.

### GENERAL SUPPRESSION

General suppression of activity occurred in 12 cases. It was incomplete in 3. General suppression fell into 3 groups: early, delayed or postoperative. Early complete suppression was a grave sign and has already been discussed. It occurred in 3 patients within 30 hours of injury and persisted until they died 2 to 4 days after injury. In each instance the patient was comatose throughout. Autopsy was done on 2 of these patients and they were found to have multiple contusions with subdural or intracerebral hematomas.

Delayed general suppression occurred in 5 cases from 3 to 10 days after injury. These were all complete suppressions, but were generally preceded and followed by a period of incomplete general suppression (Fig. 3). It did not have a serious import and usually appeared coincident with the restless, confused or irrational phase of recovery. Complete general suppression was never observed to last more than 3 days, but incomplete suppression lasted for as long as 3 weeks.

In 4 patients, nearly complete general suppression occurred after surgery. Subacute subdural collections were evacuated in 2, intracerebral hematoma in 1, and macerated brain in 1. The clinical state remained the same or improved immediately following surgery and therefore did not reflect the EEG change.

### DELTA FOCI

Delta foci, namely, focal irregular slow wave activity from $\frac{1}{2}$ to 7 per sec., occurred in 27 cases. It was random in 11, continuous in 9, and episodal in 7. Focal slow wave activity also occurred with a precise rhythm and wave form but this is considered epileptiform and discussed separately.

Delta foci, in contrast to focal suppression, shifted from one locus to another in 10 of 27 cases. From 2 to as many as 5 shifts in delta localization occurred in the course of recovery (Fig. 9 A and B). The initial strong focus was generally replaced by another more persistent one in a different area. In patients with a known focus of damage, the delta activity early was

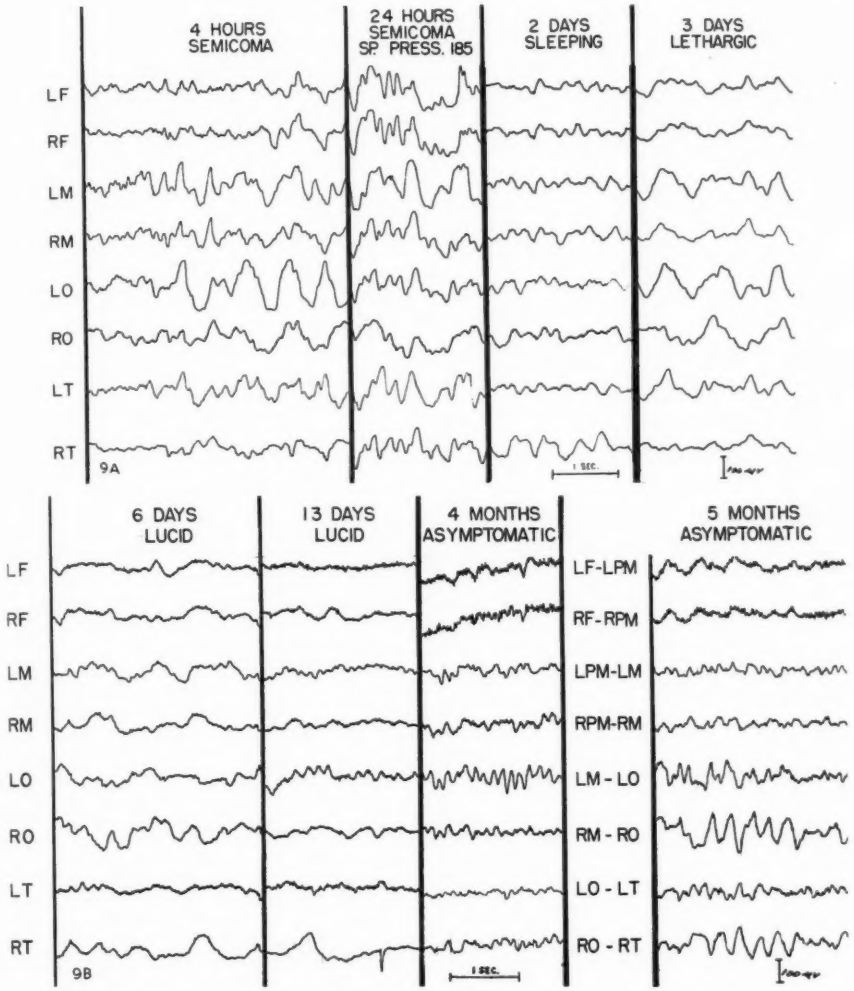


FIG. 9A, B. I.P., female, aged 2. Passenger in auto accident. Semiconscious for 24 hours. Fracture, right parietal. Left hemiplegia cleared in 17 days. No complaints when last seen 6 months after injury.

usually localized to the area of damage, but later it usually shifted to another area and then returned to the original focus.

Of the 27 patients with focal delta activity, 12 had no focal signs or complications for correlation. Seven had subdural collections and the predominant delta focus was adjacent to the lesion in 3, opposite to it in 2, and over the lesion in the other 2. Three patients had intracerebral hema-

tomas and the delta was over the lesion in each instance but was transient in 1 of them (Fig. 5). The other 5 patients had localized contusions or destruction of brain and the delta was over the lesion in 3 and adjacent to it in 2.

Delta foci were of little localizing value because of the shifting tendency; however, in the 7 cases with continuous delta at less than 1 to $1\frac{1}{2}$ per sec. the prognosis was grave. Five of these patients succumbed.

### EPILEPTIFORM ACTIVITY

Eleven patients showed seizure-like activity. These discharges were usually indistinguishable from larval seizures of idiopathic epilepsy. There were no convulsive movements in any of these patients. All but 2 were conscious. None of them was a known epileptic.

Of the 11 patients, 3 had mild injuries, 3 moderate, 4 severe and 1 had a gunshot wound and died. Only 3 had focal signs of brain damage. One moderately and 1 severely injured patient had focal seizures from the area

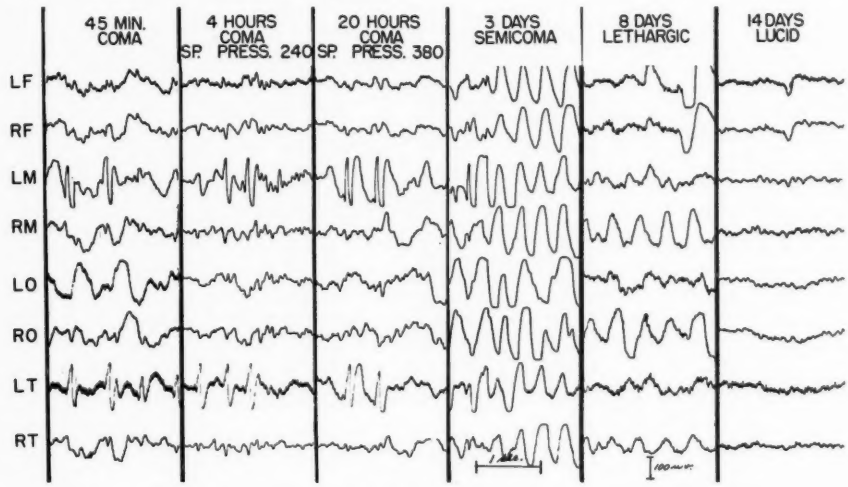


FIG. 10. H.P., female, aged 6. Fell from truck. Unconscious 10 minutes. No fracture. Aphasia and right facial weakness; cleared in 2 weeks. No follow-up.

TABLE 4

*Epileptiform activity*
*11 cases—no deaths*

| | | |
|---|---|---|
| Spike | 1 | (A child) |
| Spike and wave | 2 | (Both children) |
| 2–3 per second | 8 | (3 children, 2 teen-agers, 3 adults) |
| 5–6 per second | 3 | (1 child, 2 adults) |
| Total | 14 | |

of injury (Figs. 9 B and 10). The third, with a gunshot wound, had 5 to 6 per sec. discharges adjacent to the damaged area.

*Types of Epileptiform Activity.* Generally, only one type of discharge and frequency appeared in any one case, but in 1 patient there were multiple spikes, then spike and wave, and finally 2 and 3 per sec. waves (Fig. 10). The types of discharges and their relationship to age is shown in Table 4.

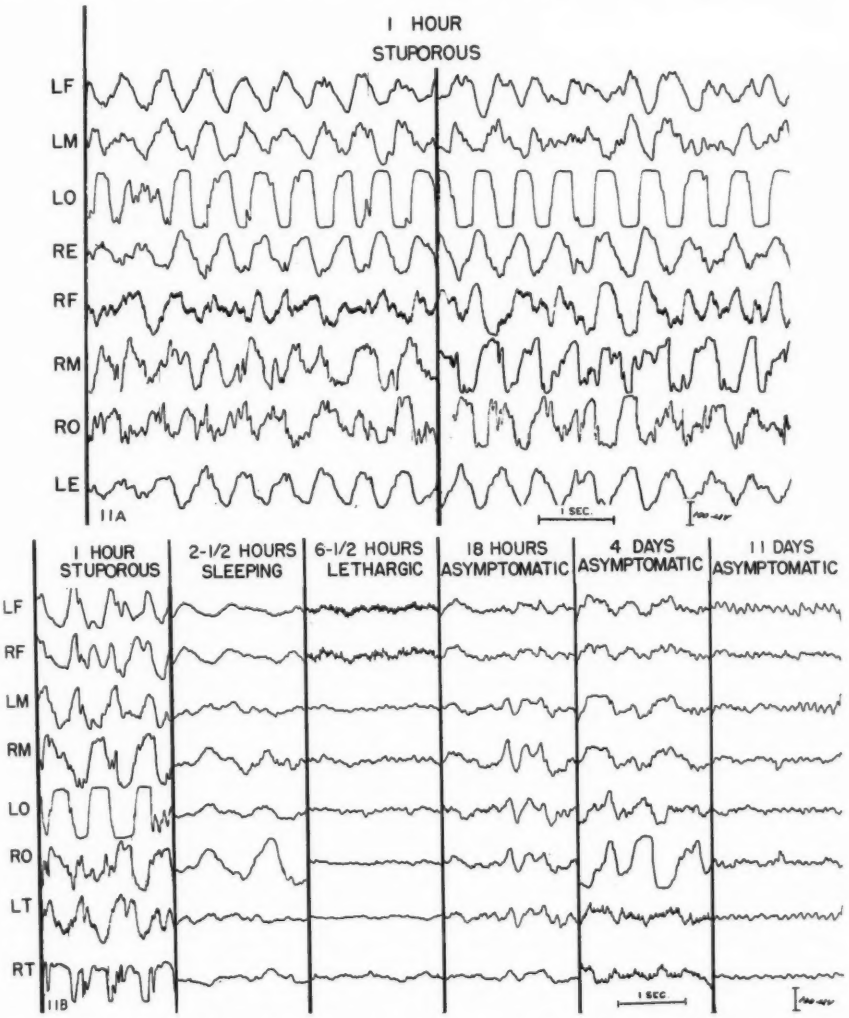


FIG. 11A, B. M.T., female, aged 3. Fell from second story. Unconscious 5 minutes. Fracture base, right. Uneventful recovery. Asymptomatic and normal EEG when last seen 7 months after injury.

The epileptiform rhythms were episodal in all but 1 case in which there was a single spike and wave discharge lasting for 3½ minutes (Fig. 11 A and B).

*Time of Onset.* In 2 patients seizure discharges were recorded within 1 hour after injury. Both were children and both were semiconscious (Figs. 10 and 11). In 4 cases they appeared in conscious, but incompletely recovered individuals from 2 to 45 days after injury (Fig. 7). The other 5 patients were clinically well when the seizure discharges appeared from 18 hours to 5½ months after injury (Fig. 12). The severity of the injury bore no relationship to the appearance or duration of epileptiform activity.

*Sites Involved.* In 4 cases the epileptiform activity appeared only in the frontal areas and was always stronger on one side. In 3 cases, there was a sharp localization and in the other 4 there were generalized seizure discharges with one hemisphere or a locus stronger than the rest. In 2 patients focal delta activity evolved into generalized, nearly continuous seizure discharges which were stronger on the side of the original delta focus. When the generalized seizure activity subsided, the original focus remained but it also subsided (Figs. 7 A and 12).

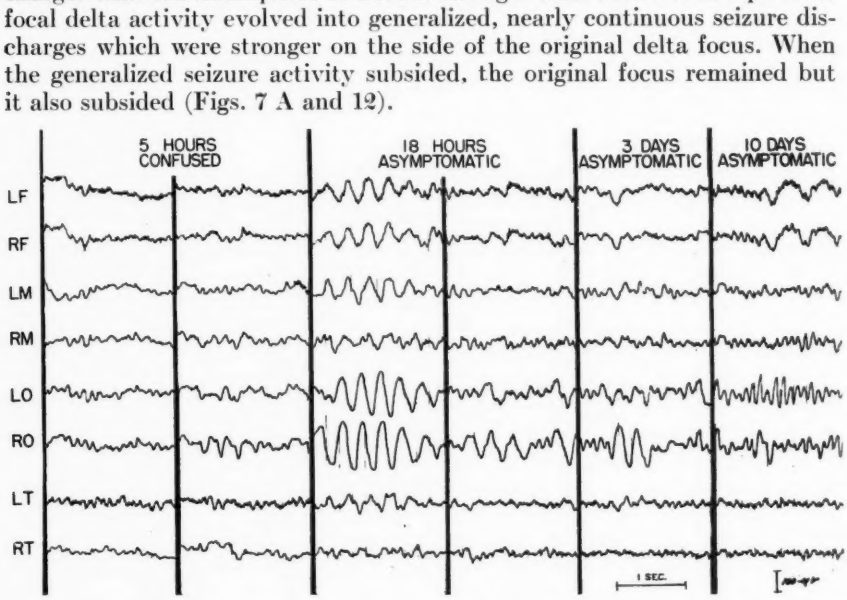


FIG. 12. F.B., female, aged 7. Fell on ice. Drowsy and confused for 8 hours. No fracture. Asymptomatic at 18 hours. No follow-up.

*Age Incidence.* In this material of 45 cases, seizure activity occurred in all 4 children and the 2 patients in their teens, but in only 5 of the 39 adults. Also, spikes or spike or wave rhythms occurred only in children. These findings indicate that the young brain is predisposed to seizure-like activity when traumatized.

## DISCUSSION

The EEG changes following acute head injuries encompass a wide variety of changes, as has been seen. This is in contrast to most of the

experimental work in animals which shows a rather stereotyped and transient change. Williams and Denny-Brown[16] found that concussion in nembutalized animals gave an immediate reduction in amplitude of the EEG activity. The fast activity was most affected, but if the concussion was severe, there was almost complete disappearance of all frequencies. Slow activity then appeared at an inconstant interval after injury and it gradually increased in frequency until it became normal. Clark and Ward[1] observed similar changes. Walker *et al.*[13] observed depression of electrical activity following impact in nembutalized animals, but in unanesthetized animals, there was a grand mal-like discharge lasting up to 1 minute after impact and this was followed by complete cessation of all activity and then resumption of normal activity. On the other hand, Dow *et al.*[3] found a variety of changes following impact, and in 2 out of 11 animals there was increase in amplitude over the control activity.

These experiments deal with concussive blows only and the immediate changes following impact, whereas, the usual patient with head injury seen by the clinician has sustained a more severe impact and EEG will reflect these changes rather than the concussive effect which has probably long since passed. Also the EEG records are obtained many minutes or hours after injury.

The explanation of both the focal and general suppressions that appear following head injury may be found in the work of Leão.[9] He found in rabbits that mechanical stimulation of the cortex produced depression and even extinction of activity in the area stimulated. With strong stimulation, the suppression may spread and become complete over the entire brain. Just such a sequence of suppression was observed in some of our cases. A focal suppression would be present on the initial examination. Later, the entire hemisphere was suppressed and still later, the entire brain. Presumably, an area of contusion or the contusion itself would act as a mechanical stimulus to initiate the focal suppression and later the general suppression.

There is general agreement in the clinical papers dealing with acute head injury that the EEG abnormality corresponds with the severity and localization of the brain injury. It is also agreed that slow activity is invariably present. However, in our material, this was true in the subacute or chronic phase of injury, but in the first few hours after the accident and in some instances up to 2 days, there were numerous examples in which there were only focal changes in an otherwise normal or only slightly slowed pattern. Many of these patients were comatose or semicomatose with these EEG findings. Only those with lethal injuries, who were to die in a few hours, showed the extremely slow activity generally ascribed to the comatose patient. All of the severely injured patients showed progressive slowing and disorganization and when focal lesions were present, the majority of them showed focal EEG abnormality. The rapidity with which the slowing occurred was commensurate with the apparent severity of the injury. Thus, there was a definite lag in the appearance of abnormality.

The 2 examples of gunshot injuries of the brain illustrate most clearly the sequence of changes in these cases. Both patients showed nearly normal EEGs soon after injury, but profound slowing and disorganization occurred in a matter of hours (Fig. 13). Since there can be no question that in these patients the gross brain damage was present from the outset, the subsequent deterioration in the EEG must be dependent upon secondary changes resulting from the initial injury. An investigation of Dennis Williams[14,15] may be of some connection here. In attempting to evaluate factors producing

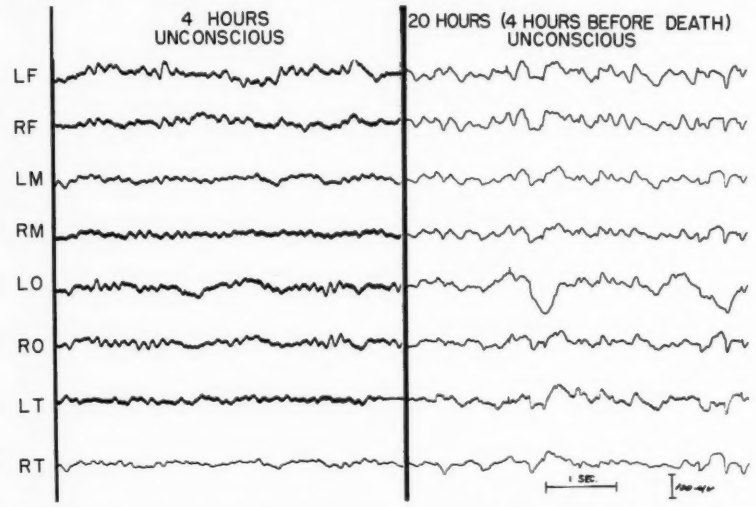


FIG. 13. C.B., male, aged 36. Gunshot wound, entrance left parietal and exit right motor. Moribund. No operation. Expired 24 hours after injury.

slow waves in increased intracranial pressure, he found that hypertonic glucose did modify the slow waves. He concluded that this effect must depend upon changes in the water balance or ionic concentration in the tissues and that slow waves may be caused by cerebral edema. Other factors that result in slowing of the cerebral electrical activity have been investigated by Williams and Gibbs. These include a lowering of the concentration of carbon dioxide, oxygen and glucose. Some such factors must be in operation in order to explain the lag in deterioration of the EEG which was so commonly seen in this material. Kennard and Nims[8] produced discrete deep-seated damage which provides yet another possible explanation for the abnormal cortical potentials. They found that thalamic lesions resulted in high amplitude slow activity. Hypothalamic lesions resulted in low amplitude slow activity and severe hypothalamic lesions resulted in cessation of practically all cortical activity. Epileptiform frequencies appeared after basal ganglia damage and combined cortical and basal ganglia injury resulted in a permanent hypersynchrony.

Tables 5 and 6 show the basic frequency and the presence and locations of suppressions and delta activity in the cases of intracerebral hematomas and acute subdural hematomas. With the exception of suppression over the site of acute subdural hematomas it is evident that there are no other consistent and reliable changes to aid in the diagnosis or localization of these lesions.

TABLE 5

*Intracerebral hematomas*

*4 cases—3 deaths*

| Basic Activity | Suppression | Delta | Operation | Result |
|---|---|---|---|---|
| 1. 5–6 | Side of lesion | None | Arteriogram | Died |
| 2. 11–12, then 7 | Over lesion | Over lesion | Hematoma evacuated | Died pneumonia |
| 3. 7–8, then flat | General | Transient over lesion | Arteriogram | Died |
| 4. 7–8 | Over lesion | Random over lesion | Hematoma evacuated | Survived |

TABLE 6

*Acute subdural hematomas*

| Basic Activity | Suppression | Delta | Time of death |
|---|---|---|---|
| *Unoperated cases* (4) | | | |
| 4–6 | None | Weak over lesion | 2 hrs. |
| 6–7 | Side of lesion (2nd day) | Random over lesion | 2 days |
| 6 (Bilat. subdur.) | Left (at 4 hrs.) | Left occiput | 18 hrs. |
| 5–6 | Over lesion (3rd day) | Opposite to lesion | 5 days |
| *Operated cases* (2) | *EEGs done postoperatively* | | |
| 9–21 | Side of lesion | Opposite to lesion | 20 hrs. |
| 15–18 | Side of lesion | General | 3 days |

## SUMMARY

1. Serial electroencephalographic studies were made of 45 patients with acute head injuries.

2. There is a lag in the appearance of abnormality in some cases up to 48 hours after injury. A person with a lethal injury may have a normal record except for focal change for some hours.

3. There is also a lag in the resolution of abnormality in comparison with the clinical state.

4. Focal suppression is common and generally indicates the site of greatest injury. It also appeared in many cases without focal signs or macroscopic lesions.

5. General suppression appearing within 30 hours of injury was uniformly fatal in this study.

6. General suppression was more common after the third day and carried no prognostic or diagnostic significance.

7. Focal delta activity shifted frequently and was therefore an unreliable finding.

8. Epileptiform activity appeared in all the young patients and only 13 per cent of the adults. There was no relationship to the severity of injury or duration of symptoms and only rarely did it arise from an area of focal damage as evidenced by focal neurological deficit.

9. Serial electroencephalography in acute head injuries is of considerable academic and practical interest. Soon after injury the EEG may show little or no abnormality even though the patient has a definite brain lesion. In the subacute and chronic phase of injury the EEG was a more valuable adjunct in diagnosis.

## REFERENCES


1. Clark, S. L., and Ward, J. W. Electroencephalogram of different cortical regions of normal and anaesthetized cats. *J. Neurophysiol.*, 1945, *8:* 99–112.
2. Cohn, R. Clinical electroencephalography. *New York: McGraw-Hill Book Co., Inc.*, 1949, vii, 639 pp.
3. Dow, R. S., Ulett, G., and Raaf, J. Electroencephalographic studies immediately following head injury. *Amer. J. Psychiat.*, 1944, *101:* 174–183.
4. Harris, H. I., Wittson, C. L., and Hunt, W. A. Value of electroencephalogram in prognosis of minor head injuries. Preliminary report. *War Med.*, 1943, *4:* 374–379.
5. Jasper, H. H., and Kershman, J. Electroencephalography. *Progr. Neurol. Psychiat.*, 1946, *1:* 372–397.
6. Jasper, H. H., Kershman, J., and Elvidge, A. Electroencephalographic studies of injury to the head. *Arch. Neurol. Psychiat., Chicago*, 1940, *44:* 328–348.
7. Jasper, H., Kershman, J., and Elvidge, A. Electroencephalography in head injury. *Res. Publ. Ass. nerv. ment. Dis.*, 1945, *24:* 388–420.
8. Kennard, M. A., and Nims, L. F. Effect on electroencephalogram of lesions of cerebral cortex and basal ganglia in *Macaca mulatta*. *J. Neurophysiol.*, 1942, *5:* 335–348.
9. Leão, A. A. P. Spreading depression of activity in the cerebral cortex. *J. Neurophysiol.*, 1944, *7:* 359–390.
10. Marmor, J., and Savitsky, N. Electroencephalography in cases of head injury. *Trans. Amer. neurol. Ass.*, 1940, 30–32.
11. Olsen, A., and Rossen, R. Neuropsychiatric and laboratory observations in 147 patients following cranio-cerebral injuries. *Minn. Med.*, 1950, *33:* 233–240.
12. Strauss, I., and Savitsky, N. The sequelae of head injury. The psychogenic factor. *Amer. J. Psychiat.*, 1934, *91:* 189–202.
13. Walker, A. E., Kollros, J. J., and Case, T. J. The physiologic basis of concussion. *J. Neurosurg.*, 1944, *1:* 103–116.
14. Williams, D. The electro-encephalogram in acute head injuries. *J. Neurol. Psychiat.*, 1941, n.s. *4:* 107–130.
15. Williams, D. The electroencephalogram in traumatic epilepsy. *J. Neurol. Neurosurg. Psychiat.*, 1944, n.s. *7:* 103–111.
16. Williams, D., and Denny-Brown, D. Cerebral electrical changes in experimental concussion. *Brain*, 1941, *64:* 223–238.
17. Williams, D., and Gibbs, F. A. Electroencephalography in clinical neurology. Its value in routine diagnosis. *Arch. Neurol. Psychiat., Chicago*, 1939, *41:* 519–534.

# THE ANGIOGRAPHIC DIAGNOSIS OF SPONTANEOUS THROMBOSIS OF THE INTERNAL AND COMMON CAROTID ARTERIES*

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DURING the past three years, it has been our practice to perform cerebral angiography on almost all patients suspected of having a brain tumor, aneurysm, or cerebral vascular anomaly. In the course of approximately 500 angiograms, we have had a group of cases in which brain tumor or aneurysm was suspected and in which it has been possible to make a positive diagnosis of spontaneous thrombosis of the internal carotid artery.

In 1936, Sjöqvist[30] reported a case in which there appeared in angiograms to be an occlusion of the internal carotid artery just above the carotid siphon; a presumptive diagnosis of a thrombosed aneurysm of the carotid was made. Attention was drawn to the angiographic diagnosis of spontaneous thrombosis of the internal carotid artery by Moniz,[25] who in 1937 described 4 such cases out of a series of 537 patients on whom angiography was done. We have been able to find in the literature a total of 101 cases of thrombosis of the internal or common carotid artery diagnosed by means of angiography. This includes only those cases in which an angiogram was made or in which the carotid was exposed with the intention of performing angiography. It also includes only those that are considered as spontaneous thrombosis. It is interesting that of these 101 cases, 84 have been in the European literature and only 17 in the American literature. This is probably a reflection of the fact that, in the past, cerebral angiography has been much more widely used in the European countries. Because of the few American reports, we are presenting our 6 cases and a review of all reported cases.

*Case 1.* J.H.H. No. 431638. A.C., a 39-year-old white male, was admitted on May 29, 1949. Approximately 2 months previously, suddenly one day he became momentarily confused, had difficulty in understanding what was said to him, and experienced a sensation of numbness over the right side of the body. For about a week before admission he was drowsy and had noticed a progressive weakness in his right arm and leg. On the morning of admission, while sitting on a sofa, he suddenly stopped talking and fell to the floor. He did not lose consciousness and had no convulsive movements, but his right hemiparesis was much more pronounced.

* Presented before the Harvey Cushing Society, April 26, 1951, Hollywood, Florida.

*Examination.* The patient was conscious but markedly aphasic, being unable to understand what was said to him and unable to speak. He had a marked right hemiparesis with diminished tendon reflexes and a Babinski response on the right. A satisfactory sensory examination could not be done because of his aphasia. B.P. was 120/70.

Blood and urine were normal. Serologic test on blood was negative for syphilis. Roentgenograms of skull and chest were normal. An EEG was reported by Dr. C. Marshall as having left-sided slowing with absence of the alpha rhythm. CSF pressure was 180 mm. of fluid; the dynamics were normal. The fluid contained a protein of 28 mg. per cent; Wassermann reaction was negative. A pneumoencephalogram was normal.

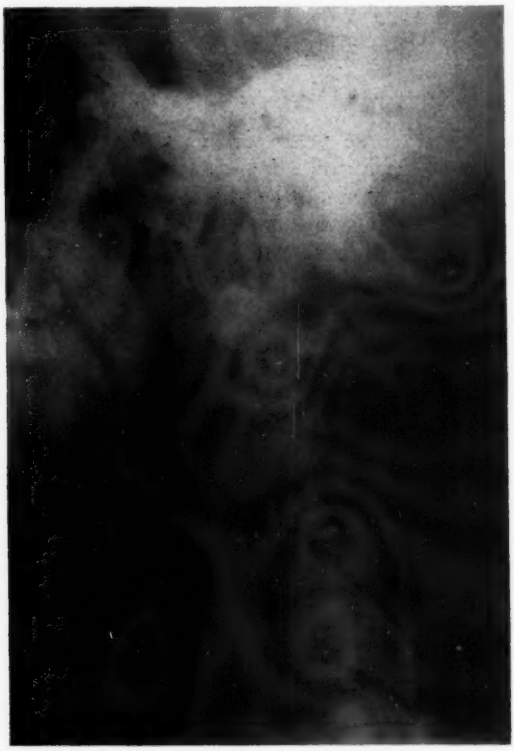

FIG. 1. *Case 1.* The left common and external carotid arteries are seen. Only a short stump of the internal carotid is demonstrated.

*Angiography.* On June 7, 1949, percutaneous left carotid arteriography was performed. Only the external carotid circulation was visualized. On June 13, 1949, arteriography was repeated and again there was filling of only the external carotid artery. The common carotid artery in the neck was outlined but only a nubbin of the internal carotid was visualized above the bifurcation (Fig. 1).

*Course.* The patient improved very slowly and was discharged on July 22, 1949.

He was able to walk but still had marked weakness of the right side. He could understand a few simple commands and was able to say his first name and a phrase, "I cannot over. . . . " A year after the onset of his illness he could say a few words such as "much better," "yes," "no," "hello." He could not name objects but could pick out the proper name. His fundi were normal. There was little change in his right hemiparesis. He became difficult to manage at home and approximately 1½ years after the onset of his illness was admitted to a State Hospital for care.

*Case 2.* J.H.H. No. 458179. J.R., a 32-year-old colored male laborer, was ad-

FIG. 2. *Case 2.* Thrombosis of the right internal carotid artery. The pneumoencephalogram demonstrates an increased amount of air in the subarachnoid space over the right cerebral hemisphere and dilatation of the right lateral ventricle.

mitted on July 22, 1948. About 3 months previously, he had experienced a sudden pain in the left side of his head and a feeling of dizziness. He took several steps, fell unconscious, and had a generalized convulsion. Upon regaining consciousness in a few minutes he noticed weakness of the left extremities, but he was able to walk home. Several days later, there developed a sudden transient numbness and paralysis of the left arm lasting about an hour. About 2 weeks prior to admission, his left arm and leg became weak but recovered during the next 7 to 8 days. He had frequent left-sided headaches.

*Examination.* The patient was cooperative and oriented. His vision was normal, but there were several small retinal hemorrhages in the region of the right macula. He had a left lower facial weakness and a marked left hemiparesis. Sensation appeared to be normal. B.P. was 136/100.

Blood and urine were normal. Serologic test on blood was negative for syphilis. Roentgenograms of chest and skull and an EEG were normal.

*Angiography.* On July 26, percutaneous right carotid arteriography was attempted but it was found impossible to obtain blood. The internal carotid artery was then exposed in the neck and was found to be thrombosed.

In a pneumoencephalogram, subsequently done, an increased amount of air in the subarachnoid space over the right cerebral hemisphere and dilatation of the right lateral ventricle were noted (Fig. 2).

*Course.* Within 2 months, the patient was improved sufficiently to work as a janitor. His left arm was only about 25 per cent weaker than the right. One year after the onset of his illness, he was feeling quite well and his only neurological abnormality was a slight left lower facial weakness.

*Case 3.* J.H.H. No. 520360. H.H., a 45-year-old white male, was admitted on Nov. 8, 1949. In September 1947 he had noticed occasional transient blindness of the right eye. His systolic B.P. at that time was said to be 130 mm. mercury. On Sept. 26, 1947, he awoke in a very confused state. He was kept in bed for about 10 days and was told that he had had a stroke affecting the left arm. His B.P. was 150 mm. of mercury. On Nov. 1, 1947, he suddenly lost the upper half of his right visual field and noticed weakness in the left arm; the weakness slowly increased in severity and gradually spread to involve the left leg. After a transient improvement he returned to work for 3 months but stopped because of further weakness of the left side. In May, 1949 he had the first of three generalized convulsions, beginning with twitching in the fingers of the left hand.

*Examination.* The patient was oriented and cooperative. Vision in the right eye was limited to counting fingers and in the left eye was 20/15. The right optic disc was atrophic. A left homonymous inferior quadrantanopsia was found on perimetric examination. There was a moderate left hemiparesis, more marked in the arm than in the leg, with impairment of position sense and stereognosis. The left tendon reflexes were hyperactive and the plantar response was extensor. B.P. was 140/80.

Blood and urine were normal. Serologic test on blood was negative for syphilis. An EEG was normal. The CSF pressure was 200 mm. of fluid; dynamics were normal. The fluid contained 2 lymphocytes per c./mm., and 50 mg. per cent of protein; Wassermann reaction was negative. Roentgenograms of skull and chest were normal.

*Angiography.* A diagnosis of aneurysm of the circle of Willis was suggested. On Nov. 9, 1949, percutaneous angiography was done on the right side. Only the external carotid vessels were seen.

Two days later in a pneumoencephalogram, a dilated right lateral ventricle with an increased amount of air in the subarachnoid space was found (Fig. 3).

*Operation.* On Nov. 16, the right carotid artery and its bifurcation were exposed. Approximately 5 mm. beyond the carotid sinus the internal carotid artery was found to be firm and without pulsation. A superior cervical ganglionectomy was performed.

*Course.* Several months later the patient's condition was unchanged although he had had no further convulsive attacks.

*Case 4.* J.H.H. No. 526011. R.W., a 46-year-old white male, was admitted on March 13, 1950 with the complaints of speech difficulty and numbness and weakness of his right side. Four to 5 years previously he had noticed in the fingers of his right

hand a numbness which in the course of a few years gradually spread to involve the entire right side. At the same time, the right side became intermittently weak. About 2 years before admission he began to have difficulty in reading and in naming objects. One year later, ventriculography was performed at another hospital.

*Examination.* The patient was alert and oriented, but had a marked motor and nominal aphasia. His vision was normal. There was minimal weakness of the right

FIG. 3. *Case 3.* Thrombosis of the right internal carotid artery. Severe cerebral atrophy with marked dilatation of the right lateral ventricle is seen in the pneumoencephalogram.

corner of the mouth. Fine movements were impaired in the right hand. The right tendon reflexes were hyperactive. There was loss of position sense, localization of touch and stereognosis over the right side of the body. B.P. was 150/86.

Blood and urine were normal. Serologic test on blood was negative for syphilis. Roentgenograms of chest were normal. Those of the skull revealed the previous burr holes.

*Angiography.* On March 15, 1950, left cerebral angiography was performed by percutaneous injection. The external carotid system was well visualized. Only a few mm. of the internal carotid at its origin filled with dye (Fig. 4).

On March 17, ventriculography was performed; the left lateral ventricle was dilated (Fig. 4).

FIG. 4. *Case 4.* The left common carotid and external carotid arteries are well visualized. Only a few mm. of the internal carotid at its origin filled with dye. A ventriculogram revealed dilatation of the left lateral ventricle.

*Case 5.* J.H.H. No. 534654. C.N., a 40-year-old white male, was admitted on April 24, 1950. On March 9, 1950, about 6:30 in the morning, his wife awoke to find the patient groaning and moaning, with excruciating headache. About 45 minutes later he had a complete paralysis of his left side. He remained conscious but became confused for 1 or 2 days. His attending physician stated that he had a left homonymous hemianopsia and bloody CSF. On the 2nd day of his illness he started to move his left leg and about the 4th or 5th day he could move his left arm. The paralysis continued to improve so that he was able to walk without support and could use his left arm for gross movements.

*Examination.* He was alert, oriented and cooperative. His vision was normal. There was weakness of the left corner of the mouth. There was a mild left hemiparesis, more marked in the arm. Tendon reflexes were hyperactive on the left side but the plantar reflex was normal. There was loss of position sense and astereognosis in the left hand. B.P. was 146/100.

Blood and urine were normal. Serologic test on blood was negative for syphilis. Roentgenograms of skull and an EEG were normal. On lumbar puncture, initial pressure was 140 mm. of CSF. The fluid contained no cells, and a protein of 28 mg. per cent; Wassermann reaction was negative.

*Angiography.* Percutaneous angiography was attempted but blood could not be obtained. The carotid sheath was exposed. The right common and external carotid arteries were normal. The internal carotid was a firm, hard cord about the size of the little finger. Diodrast injected into the common carotid artery was seen only in the external carotid artery and approximately the first 0.5 cm. of the internal carotid artery.

*Case 6.* J.H.H. No. 539729. A.R., a 59-year-old white male tailor, was admitted on June 5, 1950. For about 5 years he had been exhibiting personality changes

consisting of mental depression and general irresponsibility in business affairs. He had episodes of transient loss of consciousness, and for 4 months headaches and periods of inability to speak. On the night of admission, while talking with a friend, he suddenly fell across the table unconscious.

*Examination.* The patient was conscious, but was unable to speak. He could obey simple commands only with great difficulty. Fundi were normal and there was no impairment of visual acuity. He had weakness of the right corner of the mouth and a marked right hemiparesis, much more severe in the arm than in the leg.

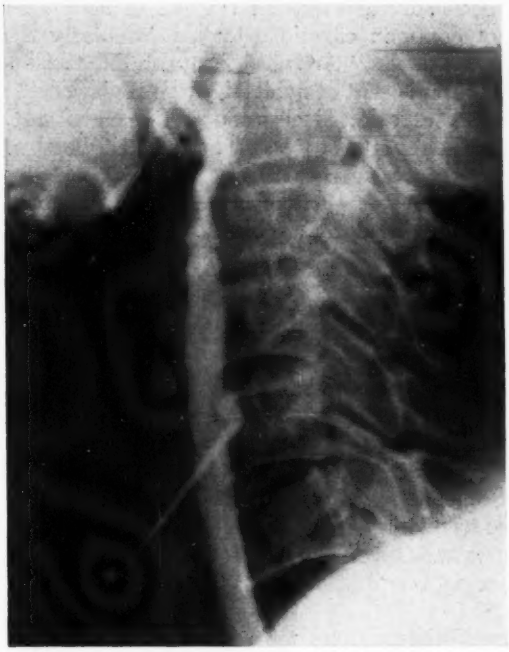

FIG. 5. *Case 6.* The needle is seen in the left common carotid artery with diodrast filling only the common and external carotid arteries.

The right tendon reflexes were hyperactive and there was an extensor plantar response. B.P. was 140/80.

Blood and urine were normal. Serologic test on blood was negative for syphilis. CSF pressure was 120 mm. of fluid; dynamics were normal. The fluid was clear and contained no cells; protein was 50 mg. per cent; Wassermann reaction was negative. Roentgenograms of the chest were normal; in those of the skull the calcified pineal gland was shifted about 1 cm. to the right.

*Angiography.* Percutaneous angiography was performed on the left side but only the external carotid system was well filled; the internal carotid was not visualized in the neck, but a small amount of diodrast was seen in the carotid siphon, presumably reaching it by way of the external carotid artery (Fig. 5).

*Operation.* The carotid artery was exposed in the neck. The common and external carotid vessels were normal but there was no pulsation in the internal nor could

blood be obtained on puncture. The superior cervical sympathetic ganglion was removed.

*Course.* Over a period of 2 months, there was slow improvement in the patient's hemiparesis, so that he could walk about without support. He became able to write simple things and obey very simple commands, but was unable to talk. Six months later he could write his name and say several simple words.

## DISCUSSION

There have been several excellent reviews of spontaneous thrombosis of the internal or common carotid artery, particularly those of Moniz,[25] Riechert,[26] Sorgo,[31] Erikson,[11] Andrell,[2] Krayenbühl,[20] and Fisher.[12] One of the most recent reports is that of Milletti,[23] who reviewed 48 cases of thrombosis of the internal carotid. Since none of the recent articles has taken into account all of the reported cases, we have felt it worthwhile to tabulate certain important features in the 107 available cases (101 plus 6 reported in this paper), of spontaneous thrombosis of the internal or common carotid artery diagnosed by angiography (Table 1).

### SYMPTOMATOLOGY

The symptoms have not been identical in all cases, nor has there been any constancy in the temporal sequence of the complaints.

*Headache.* Headache was prominent in at least one half the cases, frequently preceding any other symptom for some period of time. In some instances, the cephalalgia appeared suddenly with the onset of other symptoms. The headaches were usually severe and generalized, although at times localized to the side of the thrombosis.

*Hemiplegia.* Some degree of muscular weakness was found in 80 per cent of the cases. This frequently was noted first in the hand and arm and in 26 cases the weakness was specifically stated to be much more severe in the arm. The hemiplegia was associated usually with severe cortical sensory impairment.

*Aphasia.* Speech disturbances were present in 60 per cent of the cases. All degrees of aphasia occurred, but in many instances there was a severe motor and sensory aphasia. It is interesting that in 3 right-handed patients, thrombosis of the right internal carotid artery was associated with speech difficulty.

*Other symptoms.* Approximately 20 per cent of the patients experienced paresthesias in the paretic extremities. Twenty per cent of the patients also had convulsive attacks and one half of these were focal in nature. In 15 per cent of the patients there were mental disturbances, usually severe, consisting of depression with marked deterioration.

*Ophthalmological symptoms.* The ophthalmological findings varied considerably. In 65 of the 107 cases there was no indication of involvement of the eyes. Five patients complained of episodes of transient blindness and in 11 there was optic atrophy with visual loss. Homonymous hemianopsia was present in 12 cases. Diplopia was an uncommon symptom, being found

TABLE I

*Review of 101 reported cases of spontaneous thrombosis of internal or common carotid artery diagnosed by angiography*

| Author & Year | Age Sex Side | History | Visual | Angiogram | Treatment Course Histology | Remarks |
|---|---|---|---|---|---|---|
| Sjöqvist[30] 1936 | 48 M L | Headache. Impaired vision, 1 yr. Later sudden blindness lt. eye. | Lt. optic atrophy with blindness | Lt.—I.C. occ. at siphon. Rt.—normal. | | Assumed thrombosed aneurysm |
| Moniz *et al.*[25] 1937 | | | | | | |
| Case 1 | 46 M R | Headache. Vertigo. Weakness rt. arm. | Rt. optic atrophy | Rt.—I.C. occ. at origin. Lt.—both ant. & mid. cer. visualized. | | +Wassermann |
| Case 2 | 40 M R | Headache. Fainting spells. Paresthesias lt. hand. Weakness lt. arm. Convulsion lt. side. Sudden lt. hemiplegia. | Diplopia | Rt.—I.C. occ. at origin. Lt.—increased circulation. | | Papilledema in 1 of the 4 cases. |
| Case 3 | 52 M L | Headache. Sudden paresis rt. arm. Later convulsions. Later aphasia. | | Lt.—I.C. occ. at origin. Rt.—both ant. cer. visualized. | | |
| Case 4 | 43 M L | Headache, 8 yrs. Sudden aphasia. Later improved. Later hemiplegia. | | Lt.—I.C. occ. at origin. Rt.—normal. | | |
| Shimidzu[28] 1937 | 59 M L | Progressive dementia and aphasia, 12 yrs. | | Lt.—I.C. occ. 3 cm. above origin. Rt.—?filling of lt. mid. cer. | Died 3 yrs. later of pneumonia | Air—atrophy lt. frontotemp. |

TABLE 1—(*Continued*)

| Author & Year | Age Sex Side | History | Visual | Angiogram | Treatment Course Histology | Remarks |
|---|---|---|---|---|---|---|
| Riechert[26] 1938 | | | | | | |
| Case 1 | 55 M R | Headache. Sudden paralysis lt. side. Depression. | | Rt.—I.C. occ. at origin. Lt.—both ant. cer. visualized. | Ex. bifur. Improved. Arterios. | |
| Case 2 | 51 M L | Headache. Weakness lt. foot. Paresthesias. Depression. | | Lt.—I.C. occ. at origin. Rt.—normal. | Ex. bifur. Improved. Arterios. | Air—dil. vents. more on lt. |
| Case 3 | 13 M R | Headache. Paresthesias rt. side face. Lt. hemiparesis. | Ptosis. Fixed pupil. Papilledema. | Rt.—I.C. occ. at origin. Lt.—normal. | | Air—rt. ant. horn dil. |
| Siegert[29] 1938 | | | | | | |
| Case 1 | 58 M R | Transient hemiplegia and aphasia. | Diplopia. Lt. hom. hemianopsia | Rt.—I.C. occ. at origin. Lt.—both ant. cer. visualized. | No change. | |
| Case 2 | 57 F R | Sudden diplopia with headache. | Ptosis. 6th weakness. Rt. pupil small. | Rt.—I.C. occ. at origin. Lt.—both ant. cer. visualized. | Died 1 hr. after bilat. angiogram. | |
| Chao *et al.*[8] 1938 | | | | | | |
| Case 1 | 47 M L | Transient hemiplegia and aphasia. | | Lt.—I.C. occ. at origin. | Ex. vessel. Improved. | Hypersensitive lt. carotid sinus. |
| Case 2 | 27 M L | Sudden aphasia. Next day rt. hemiplegia. | Nasal hemianopsia, lt. eye. Contraction upper temp. field, rt. eye. | Lt.—I.C. occ. at origin. | Ex. vessel. Improved. | |
| Sorgo[31] 1939 | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | L | | upper temp. field, rt. eye. | | | |
| Sorgo[31] 1939 | | | | | | |
| Case 1 | 49 M R | Paresthesias lt. hand. Speech difficulty. Drooping lt. corner mouth. Improved. Recurred in 2 mos. | | Rt.—I.C. occ. at origin. Lt.—both ant. cer. visualized. | Working 3 yrs. later. | |
| Case 2 | 56 M L | Vomiting and dizziness, 4 wks. Focal convulsions rt. side. Paralysis rt. side, 10 days. Head injury 2 yrs. ago. | Lt. optic atrophy. Lt. pupil small. | Lt.—I.C. occ. at origin. | Improved; working. | Air—dil. vents. |
| Case 3 | 42 M L | 1936—Headache, vomiting, unconsciousness. 1937—Aphasia, paresthesias rt. hand. Mental deterioration. | Lt. pupil small. | Lt.—I.C. occ. at origin. | | Air—dil. vents. Atrophy lt. frontal lobe. |
| Case 4 | 45 M L | 2 yrs. ago, weakness rt. arm. 6 mos. ago, sudden paralysis rt. hand; slow improvement. 4 weeks ago, apraxia. Head injury, 1930. | | Lt.—I.C. occ. at origin. | Died in 2 days of pneumonia. Autopsy: severe arterios. Cer. T.A.O. | |
| Case 5 | 34 M L | 14 days, headache. 12 days, gradual paralysis rt. side. | Lt. pupil small. Lt. intern. rectus weak. | Lt.—I.C. occ. 4 cm. above origin. | Died in 3 mos. Autopsy. | |
| Case 6 | 29 M L | Speech difficulty long time. Headache, dizziness, convulsions, 14 mos. Unconsciousness, 36 hrs. | | Lt.—I.C. occ. at origin. | | Air—normal. |
| Case 7 | 22 M R | Sudden headache and unconsciousness. 15 mins. later lt. arm and leg weak. Gradual improvement. | Rt. pupil small. | Rt.—I.C. occ. at origin. | | Air—dil. vents. |
| Case 8 | 36 M L | 2 yrs. ago—rt. arm weak 2 hrs. Headache, 1 yr. Then sudden rt. hemiplegia and aphasia. Hypesthesia lt. 5th. | Slight rt. ptosis. Lt. pupil small. | Lt.—I.C. occ. at origin. | Sympathectomy. Died in 2 days. Autopsy: Severe arterios. | Air—dil. vents. |

TABLE 1—(*Continued*)

| Author & Year | Age Sex Side | History | Visual | Angiogram | Treatment Course Histology | Remarks |
|---|---|---|---|---|---|---|
| Lohr (from Krieg)[21] 1939 | | | | | | |
| Case 1 | 67 F L | 4 wks. ago, sudden paralysis rt. hand. Sensory aphasia. Gradual paralysis rt. side. | | Lt.—I.C. occ. at origin. Rt.—severe arterios. | Died 1 wk. Autopsy. | BP, 235/135. |
| Case 2 | 45 F L | 6 wks. ago, sudden loss of consciousness, rt. hemiplegia, aphasia. | | Lt.—I.C. occ. at origin. Rt.—both ant. cer. visualized. | Unchanged | |
| Case 3 | 51 M R | 4 wks. ago, sudden loss of consciousness, lt. hemiplegia. Marked mental deterioration. | | Rt.—I.C. occ. at origin. Lt.—normal. | Died in 3 mos. | Air—dil. vents. more on rt. |
| Takahashi[34] 1940 | 28 F Bilat. | Age 20—headache. Absence radial pulse. Aniscoria. Later impaired vision rt. eye. | Impaired vision rt. eye. Cataract lt. eye. | Occ. of both C.C. Vertebral supply to all of brain. | T.A.O. | |
| Galdston *et al.*[14] 1941 | | | | | | |
| Case 1 | 52 M L | Sudden speech loss and rt. hemiplegia. Occasional gen. convulsion. | | Lt.—occ. C.C., I.C., E.C. Rt.—normal. | Ex. bifur. Arterios. | BP, 210/150. Air—dil. vents. |
| Case 2 | 52 M L | Sudden confusion and aphasia. Similar episode 4 yrs. ago. Gen. convulsion. | | Lt.—occ. C.C., I.C., E.C. Rt.—both ant. and mid. cer. visualized. | Ex. bifur. Arterios. | BP, 190/110. |
| Tölle[36] 1942 | M Bilat. | Speech disturbance. Paralysis rt. side. | | Bilat. occ. I.C. Vertebral normal. | Ex. 1 cm. each I.C. T.A.O. | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Sponer[32] 1942 | | | | | | |
| Case 1 | 51 M L | 1932—convulsions, rt. side. 1939—weakness rt. side. Improved. Two mos. later rt. hemiplegia and aphasia. Head injury, 1915. | Lt. pupil small. Rt. hom. hemianopsia. | Lt.—I.C. occ. at siphon. Rt.—filled both sides. | Died in 2 days. Autopsy: Arterios. | Air—dil. vents. |
| Case 2 | 57 F L | Fainting spell. Rt. hemiplegia. Demented. | Rt. hom. hemianopsia. | Lt.—I.C. occ. at origin. | Died in 3 wks. Pneumonia. Autopsy: Arterios. | |
| Case 3 | 46 M R | Headache. Sudden paralysis lt. hand. Improved. Recurred. | | Rt.—I.C. occ. at origin. | No change. | |
| Erikson[11] 1943 | | | | | | |
| Case 1 | 48 M R | Sudden weakness lt. arm; improved. 9 mos. later recurred with paralysis lt. side. Lt. 5th involved. | | Rt.—I.C. occ. 1.5 cm. above origin. | Ex. of vessel. | Air—dil. vents. |
| Case 2 | 52 M R | Headache. Weakness lt. side, 2½ yrs. | | Rt.—I.C. occ. 3 cm. above origin. | | Air—dil. vents. |
| Case 3 | 33 M R | Age 25—headaches. Age 27—lt. hemiplegia; improvement. Focal convulsions. Aphasia. Age 15—head injury. | | Rt.—I.C. occ. at origin. | | Air—rt. vent. dil. |
| Case 4 | 45 M L | Sudden aphasia, headache and rt. facial weakness. | | Lt.—I.C. occ. 3 cm. above origin. | Ex. vessel. Recanalization. Intima thickened. Round-cell infiltration. | Air—normal. |
| Case 5 | 28 M R | Headache many yrs. Hit on head 1 day ago. Lt. hemiplegia and aphasia. | | Rt.—I.C. occ. at siphon. | Died. Autopsy: cer. softening. | |

TABLE 1—(*Continued*)

| Author & Year | Age Sex Side | History | Visual | Angiogram | Treatment Course Histology | Remarks |
|---|---|---|---|---|---|---|
| Case 6 | 43 M L | Headache long time. Sudden hemiplegia and aphasia. | Rt. ptosis. | Lt.—I.C. occ. at siphon. | | |
| Case 7 | 38 F L | Sudden rt. hemiplegia and aphasia. | | Lt.—I.C. occ. 2 cm. above origin. | | Air—lt. vent. dil. |
| Case 8 | 48 F L | Headache 1 yr. 9 mos. ago—unconscious and hemiplegic 1 day. 6 mos., rt. hemiplegia and aphasia. | | Lt.—I.C. occ. 5 mm. above origin. | | |
| Case 9 | 33 M L | 6 mos., speech difficulty, weakness rt. leg, headache. | | Lt.—I.C. occ. at origin. Rt.—both ant. and mid. cer. visualized. | Ex. vessel. Intima normal. Thickened adventitia and media. | |
| Andrell[2] 1943 | | | | | | |
| Case 1 | 45 M L | Headache 1 yr. Acute aphasia. | | Lt.—I.C. occ. 3 cm. above origin. | Ex. vessel. Improved; working. Intima thickened. Perivascular round cells. | Air—normal |
| Case 2 | 28 M R | Headache several yrs. Convulsions. Sudden lt. hemiplegia. Hit on head 10 yrs. ago. | | Rt.—I.C. occ. at origin. | Slight improvement. | Air—dil. rt. vent. |
| Case 3 | 49 M L | Headache 1 yr. Transient paresis rt. arm. Sudden aphasia and rt. hemiplegia. | | Lt.—I.C. occ. 1 cm. above origin. | Died. Cer. T.A.O. | Air—dil. lt. vent. |

| | | | | | | |
|---|---|---|---|---|---|---|
| Case 4 | 38<br>F<br>L | Sudden aphasia and rt. hemiplegia. | | Lt.—I.C. occ. 2 cm. above origin. | Slight improvement. | Air—dil. lt. vent. |
| Case 5 | 32<br>M<br>R | Episodes transient aphasia, several wks. Sudden lt. hemiplegia and aphasia. | Thrombosis central retinal artery. | Rt.—I.C. occ. at siphon. | Improved. | |
| Case 6 | 49<br>F<br>L | 1 attack unconsciousness. Transient weakness rt. side and aphasia. | Rt. hom. hemianopsia. | Lt.—I.C. occ. 1.5 cm. above origin. | | BP, 195/125. |
| Case 7 | 34<br>M<br>L | Difficulty writing. Episodes of aphasia and weakness rt. side. | Episodes of transient blindness. | Lt.—I.C. occ. at origin. | Ex. vessel. No improvement. T.A.O.? | Air—dil. lt. vent. |
| Case 8 | 44<br>M<br>R | Progressive lt. hemiplegia. Lt.-handed. Some aphasia. | | Irregular filling of siphon. | Died in several mos. | Air—dil. lt. vent. |
| Case 9 | 60<br>M<br>L | Progressive numbness and weakness rt. side. Aphasia. | Paralysis of upward gaze. | Irregular filling of siphon. | | BP, 220/110. Air—dil. rt. vent. |
| Krayenbühl & Weber[20] 1944 | | | | | | |
| Case 1 | 15<br>F<br>R | 1941—loss of consciousness and paralysis lt. side. Improved. 1943—again paralysis lt. side. | Retinal pressure, diastolic: Rt. 40/45; Lt. 40. | Rt.—I.C. occ. 1 cm. above origin. | Ex. vessel. No inflammatory reaction. | |
| Case 2 | 19<br>M<br>L | Weakness rt. hand; improved; recurred. | | Lt.—I.C. occ. at origin. | Improved | CSF, 39 cells. Air—dil. lt. vent. |
| Case 3 | 37<br>M<br>L | Headache 1 yr. 1942—vomiting, unconsciousness. 1943—sudden aphasia and weakness rt. hand. Then sudden rt. hemiplegia and aphasia. | Lt. pupil small. | Lt.—I.C. occ. 2 cm. above origin. | Ex. vessel. Improved. Thickened intima. | CSF, 200 cells. Air—dil. lt. vent. |

TABLE 1—(*Continued*)

| Author & Year | Age Sex Side | History | Visual | Angiogram | Treatment Course Histology | Remarks |
|---|---|---|---|---|---|---|
| Case 4 | 39 F L | Recurrent unconsciousness. Sudden rt. hemiplegia, aphasia, vomiting. | | Lt.—I.C. occ. 1.5 cm. above origin. | Improved 3 yrs. later. | |
| Case 5 | 42 M L | Sudden aphasia and headache. | | Lt.—I.C. occ. at siphon. | Ex. vessel. T.A.O. | Air—dil. lt. vent. |
| Case 6 | 42 M L | Transient weakness rt. hand, aphasia. | | Lt.—I.C. occ. at origin. | Ex. vessel. T.A.O. | Air—dil. lt. vent. |
| Case 7 | 45 M R | Headache many yrs. Sudden lt. hemiplegia. | Retinal pressure diastolic; Rt. 40; Lt. 40. | Rt.—I.C. occ. 4 cm. above origin. | Ex. vessel. No improvement. T.A.O. | |
| Case 8 | 45 M L | Jerking rt. hand. 6 mos. later sudden paralysis rt. arm and aphasia. | Transient diplopia. | Lt.—I.C. occ. 4 cm. above origin. | | |
| Case 9 | 48 M L | 1939—speech difficulty. 1940—sudden paralysis rt. hand. Speech worse. Gradual rt. hemiplegia. | | Lt.—I.C. occ. at origin. | | |
| Case 10 | 54 M L | Progressive rt. hemiplegia and aphasia. | Transient diplopia. Lt. Horner's. | Lt.—I.C. occ. at siphon. | | Air—dil. lt. vent. |
| Case 11 | 54 M R | Progressive weakness lt. arm. Disoriented. | | Rt.—I.C. occ. at siphon. | Died. Autopsy. T.A.O. | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Trotot[38]<br>1944 | 55<br>M<br>L | Weakness rt. hand. Gradual paralysis rt. arm. 3 wks. later aphasia. | Retinal pressure: Rt. 50/60; Lt. 20. Rt. hom. hemianopsia. | Lt.—I.C. occ. at origin.<br>Rt.—normal. | | Air—normal. |
| Krayenbühl[19]<br>1945 | 43<br>M<br>L | Weakness rt. hand, aphasia. Improved. 2 yrs. later recurred. Improved. Sudden rt. hemiplegia and aphasia. | Bilat. retinal pressure: diastolic, 20–25; systolic, 30–35. Rt. hom. hemianopsia. | Lt.—I.C. occ. at origin. | Ex. vessel. Intima thickened. | Intermittent claudication. Rt. dorsalis pedis absent. |
| Frövig[13]<br>1946 | 21<br>F<br>Bilat. | Headache. Transient numbness rt. hand. Later transient aphasia, and weakness, numbness rt. leg. Fainting spells. Twitchings rt. hand. Weakness and numbness lt. side. No arterial pulsations in arms or neck. | Rt. cataract. Rt. pupil large, no light reaction. Light perception. Lt. 5/15. Retinal pressure 20. | Bilat. occ. C.C. Vertebral—visualized frontal, parietal vessels. | Ex. rt. C.C. Dilatol and heparin. No improvement. Proliferated intima; media broken. No inflammatory cells. T.A.O.? | Air—slight atrophy on lt. |
| Govons & Grant[16]<br>1946 | | | | | | |
| Case 1 | 24<br>M<br>L | Unconscious spells since infancy. | | Lt.—I.C. occ. at origin. | | Air—dil. vents. |
| Case 2 | 25<br>M<br>R | Headaches 2 yrs. Thick speech 1½ yrs. Seizures of spinning. 2 episodes unconsciousness. | Paralysis rt. int. rectus. Rt. pupil large. | Rt.—I.C. occ. at siphon.<br>Lt.—normal. | ? cerebral T.A.O. | CSF bloody during 1 attack headache and unconsciousness. Peripheral arterial disease in rt. foot. Air—excess over cerebellum. |
| Case 3 | 60<br>M<br>L | Transient attacks of aphasia and paralysis, rt. side. | | Lt.—I.C. occ. at origin. | | |

TABLE 1—(*Continued*)

| Author & Year | Age Sex Side | History | Visual | Angiogram | Treatment Course Histology | Remarks |
|---|---|---|---|---|---|---|
| Moniz[24] 1947 | | | | | | |
| Case 1 | 39 M R | Lt. hemiplegia age 20 with typhoid. Epilepsy at age 26. | | Rt.—I.C. occ. 1 cm. above origin. Lt.—normal. | | |
| Case 2 | 14 M L | Rt. Jacksonian attacks every mo. since age 9. Mild rt. hemiplegia. | | Lt.—I.C. occ. at origin. Rt.—both ant. cer. visualized. | | |
| Case 3 | 56 M R | Headache and visual disturbance. | Vision: Rt. 6/10; Lt. 0. Optic atrophy. | Rt.—I.C. occ. at origin. Lt.—normal. | | |
| Barré *et al.*[4,5] 1947 | | | | | | |
| Case 1 | 56 M L | 1935—progressive hemiplegia. Later convulsive attacks rt. side. | Retinal pressure: diastolic equal bilat. | Lt.—I.C. occ. 2 cm. above origin. E.C. large; also filled rt. siphon and both ant. cer. | Sympathectomy. No improvement. | Air—lt. vent. dil. |
| Case 2 | 55 M L | Progressive paralysis rt. arm; improved. Later aphasia and hemiplegia. | | Lt.—I.C. occ. at origin. | Sympathectomy. Ex. vessel. No improvement. Arterios. Recanalization. Rethrombosis. | |
| Taptas & Pecker[35] 1948 | 39 M L | Sudden rt. hemiplegia and aphasia. | | Lt.—I.C. occ. 2 cm. above origin. | Much improved. | BP, 190. |

| | | | | | | |
|---|---|---|---|---|---|---|
| Wolfe[41] 1948 | 26 F L | Sudden rt. hemiplegia, aphasia, headache. Mental deterioration. | | Lt.—I.C. occ. 2 cm. above origin. | Periarterial stripping; became worse. Sympathectomy and ex. I.C., E.C. and C.C.: no change. Recanalization. Rethrombosis. ?T.A.O. Degen. media; slight inflammatory reaction. | Air—atrophy. |
| James[16] 1949 | | | | | | |
| Case 1 | 42 M L | Progressive headache, rt. hemiplegia and aphasia. | Lt. hom. hemianopsia. | Lt.—I.C. occ. 2 cm. above origin. | Slight improvement. | Air—lt. vent. dil. |
| Case 2 | 52 M L | Progressive rt. hemiplegia. Numbness rt. side. Marked mental deterioration. | | Lt.—I.C. occ. 2 cm. above origin. | No change. | Air—lt. vent. dil. |
| Case 3 | 38 M R | Sudden headache and lt. hemiplegia. | | Rt.—I.C. occ. 3 cm. above origin. | Rt. temp. burr hole—15 cc. dark clot in rt. temp. lobe. Improved. | CSF bloody. Aneurysm? |
| Le Beau *et al.*[22] 1949 | 46 F L | 1943—headaches. 1944—diplopia. 1945—lt. ptosis. 1948—lt. 3rd and 6th palsy. Head injury in 1940. | Lt. 3rd and 6th palsy. | Lt.—I.C. occ. 2 cm. above origin. | | Suspect thrombosed aneurysm. |
| Ameli & Ashby[1] 1949 | | | | | | |
| Case 1 | 41 M L | Sudden rt. hemiplegia and aphasia. | | Lt.—I.C. occ. at origin. | Improved. | CSF bloody. |
| Case 2 | 57 M L | Weakness rt. leg, improved. Later weakness rt. arm. Later rt. hemiplegia and aphasia. | | Lt.—Intracranial portion of vessel narrowed like canalization of thrombus. | | Intermittent claudication. No pulsation in dorsalis pedis or popliteal arteries. |

TABLE 1—(*Continued*)

| Author & Year | Age Sex Side | History | Visual | Angiogram | Treatment Course Histology | Remarks |
|---|---|---|---|---|---|---|
| Case 3 | 58 M L | Weakness rt. side. Later transient speech defect. Later severe aphasia. | Lt. pupil small. Lt. eye blind. | Lt.—I.C. occ. at origin. | | |
| Case 4 | 51 M L | Speech difficulty 4 yrs. Progressive weakness and numbness rt. arm 3 yrs. Fainting attacks every 2–3 mos. | | Lt.—C.C. occ.<br>Rt.—both ant. and mid. cer. visualized. | | Air—atrophy, more on lt. |
| Case 5 | 48 M R | Progressive weakness of lt. side. | | Rt.—Intracranial portion very narrowed. | | Air—normal. |
| Case 6 | 57 M L | 2 yrs. weakness rt. foot. 2 mos. paresthesias rt. side, slight rt. hemiplegia. | | Lt.—I.C. occ. at siphon. | | Air—subarachnoid spaces larger on lt. |
| Budínová-Smělá *et al.*[7] 1949 | | | | | | |
| Case 1 | 53 F L | Hemiplegia | | Lt.—I.C. occ. at origin. | Ex. vessel | +Wassermann |
| Case 2 | 59 F L | Hemiplegia and aphasia. | | Lt.—I.C. occ. at origin. | | Air—hydrocephalus. |
| Case 3 | 44 F R | Spastic hemiparesis. Head injury 8 yrs. ago. | | Rt.—I.C. occ. at origin. | Ex. vessel. | |
| Case 4 | 53 M Bilat. | Head injury 8 yrs. ago, followed by slow quadriparesis. | | I.C. occ. bilat. | Ex. vessel. | BP, 200/120. Air—diffuse atrophy. |
| Case 5 | 66 M L | Paroxysmal aphasia and agraphia. | | Lt.—I.C. occ. at origin. | Ex. vessel. | |
| Barré *et al.*[6] | 54 | Series of convulsive attacks lt. | Transient blindness | Rt.—I.C. occ. | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Barré *et al.*[6] 1950 | 54 M R | Series of convulsive attacks lt. arm. Transient lt. hemiparesis. | Transient blindness rt. eye. | Rt.—I.C. occ. just above origin. | Sympathectomy. Ex. vessel. | Air—normal. |
| Milletti[23] 1950 | | | | | | |
| Case 1 | 46 M R | Headache 1½ yrs. Transient lt. weakness. 10 mos. later, increased weakness lt. side. | Transient blurred vision. Relative hom. hemianopsia. | Rt.—I.C. occ. at origin. | Much improved. | Air—rt. vent. dil. |
| Case 2 | 37 M R | 1944—transient weakness lt. arm. Lt. focal fits. 1945—progressive weakness lt. side. | Retinal pressure: diastolic, rt. 5, lt. 40; systolic, rt. 40, lt. 110. | Rt.—I.C. occ. at origin. | Improved | Air—rt. vent. dil. 1948—T.A.O. of lt. leg; ulcer and no arterial pulsations. |
| Webster *et al.*[40] 1950 | | | | | | |
| Case 1 | 24 M R | Sudden lt. hemiplegia and blindness rt. eye. | Rt. eye blind. Optic atrophy. | C.C., I.C., E.C. occ. | Ex. bifur. No improvement. Arterios. | |
| Case 2 | 71 F L | Sudden rt. hemiplegia and aphasia | | C.C., I.C., E.C. occ. | Ex. bifur. No improvement. Arterios. | |
| Case 3 | 63 M L | Progressive blurring vision. Twitching lt. side face. | Lt. optic atrophy. Loss of inferior and temporal field, lt. eye. | C.C., I.C., E.C. occ. | Ex. bifur. No improvement. Marked atheromatous changes. | |
| Case 4 | 52 F L | Sudden paralysis and aphasia. | | Lt.—I.C. occ. at origin. | Ex. vessel. Much improved. Atheromatous changes. | BP, 200/110 |
| Sugar *et al.*[33] 1950 | | | | | | |
| Case 1 | 41 M L | Rt. hemiplegia and aphasia, 3 times in 2 yrs. Then sudden hemiplegia and aphasia. Improved. 2 yrs. later, recurred. | Rt. hom. hemianopsia. | Lt.—First occ. at siphon. 2 yrs. later occ. 2 cm. above origin. | | |

TABLE 1—(*Continued*)

| Author & Year | Age Sex Side | History | Visual | Angiogram | Treatment Course Histology | Remarks |
|---|---|---|---|---|---|---|
| Case 2 | 26 M R | Sudden lt. hemiplegia and hemianesthesia. 5, 7, 8, 9, 10, 11 and 12 involved on lt. side. Partial 3rd on rt. | Rt. optic atrophy. Ptosis. | Rt.—I.C. occ. just above origin. | Ex. vessel. | |
| Fisher[12] 1951 | | | | | | |
| Case 1 | 62 M L | Transient rt. numbness and aphasia. Sudden rt. hemiplegia and aphasia. | | Lt.—I.C. occ. just above bifur. | | |
| Case 2 | 60 M R | Rt.-sided headaches, 2 yrs. Transient weakness and numbness lt. arm. Sudden lt. hemiplegia. | Several episodes transient blindness rt. eye. Hom. hemianopsia. | Rt.—I.C. occ. at origin. | Slightly improved. | |
| Torkildsen & Koppang[37] 1951 | | | | | | |
| Case 1 | 46 M L | Motor dysphasia. 2 wks. later, gradual progressive rt. hemiplegia. Later improvement. | | Lt.—I.C. occ. just above origin. Rt.—ant. and mid. cer. visualized bilat. | | |
| Case 3 | 38 F L | 1938—head injury; unconscious 1 hr. Since then, headaches, more on lt. Paresthesias rt. arm and leg. | | Lt.—I.C. occ. at siphon. Rt.—ant. and mid. cer. visualized bilat. | | |

ant. =anterior
arterios. =arteriosclerosis
bifur. =bifurcation
C.C. =common carotid
cer. =cerebral
dil. =dilated
E.C. =external carotid
ex. =excision
I.C. =internal carotid
lt. =left
mid. =middle
occ. =occluded
rt. =right
T.A.O. =thrombo-angiitis obliterans
vent. =ventricle

in only 6 cases. Ptosis was present in 6. Two patients had papilledema. The pupillary changes were of interest. In one patient the ipsilateral pupil was fixed, in 3 it was larger, but in 10 it was smaller. The small pupil has been interpreted by Milletti[23] as being secondary to involvement of the sympathetic fibers around the carotid vessels. Each of the 2 patients with bilateral occlusion of the common carotid artery had a cataract of one eye. Milletti has recently pointed out the value of measuring the systolic retinal pressure. The retinal pressure has been reported in 7 cases. In 1 of these (Krayenbühl) a comparison of the two sides was not made. In the other 6 the diastolic retinal pressure was found to be equal in the two sides in 4 cases, and decreased on the side of the thrombosis in the other 2. In a series of patients with occlusion of the internal carotid, Milletti pointed out that the systolic retinal pressure is decreased on the side of the lesion, although the values of the diastolic retinal arterial pressure may be equal. He further emphasized that compression of the carotid artery on the side of the occlusion results in no change in the systolic retinal pressure, whereas compression on the opposite side causes a decrease of retinal arterial pressure on both sides. This observation he called the "tonometric retinal syndrome."

## CLINICAL COURSE

Of more interest than reviewing and listing the various symptoms that have occurred is the fact that the onset of the illness usually follows one of three different patterns.

(1) *Sudden catastrophic onset.* About 35 per cent of the patients had a sudden apoplectic type of onset. There was usually loss of consciousness, severe headache and the rapid onset of hemiplegia, and aphasia if the left side was involved.

(2) *Slowly progressive course.* Approximately 25 per cent of the patients had a slowly progressive onset. There was frequently a period of severe headaches of several months' to several years' duration. Sporadic convulsive attacks occurred in some cases. Paresthesias and weakness of the contralateral extremities appeared—frequently in the hand and arm first, gradually spreading to involve the leg. Some degree of mental regression and speech impairment was common. Just before seeking medical care there was usually a rapid and sudden increase in the symptomatology.

(3) *Transient attacks.* This type of history was found in about 40 per cent of the cases and was characterized by transient attacks of headache, hemiparesis, paresthesias, and aphasia. Usually, with a rather sudden onset, the attacks lasted only a few minutes to an hour, clearing either suddenly or gradually. Some residual paralysis or speech difficulty might persist until the next attack, weeks or months later. Not infrequently such a series of transient attacks was terminated by a sudden hemiplegia and aphasia.

## INCIDENCE

*Age and Sex Distribution.* There was a definite preponderance of males; of the 107 patients, 87 were males and only 20 females. There also appeared

to be a definite predilection for the 30–60 age group, although the range varied from the youngest of 13 to the oldest of 71 (Table 2).

TABLE 2

*Age distribution*

| Age in Years | Number of Patients |
|---|---|
| 11–20 | 4 |
| 21–30 | 12 |
| 31–40 | 19 |
| 41–50 | 34 |
| 51–60 | 32 |
| 61–70 | 4 |
| 71–80 | 1 |
| Not given | 1 |
| Total | 107 |

*Side Involved.* In 65 per cent of the 107 cases the thrombosis occurred on the left side, so that there seems to be a definite tendency for the left side to be more frequently involved. The significance of this is not clear. It has been suggested that the difference in anatomical relationships of the two vessels might be a factor.

## ANGIOGRAPHIC FINDINGS

Since, in the great majority of cases, the patient was suspected of having a brain tumor or an intracranial aneurysm (4 of our patients were thought to have a brain tumor and 2 an aneurysm), the angiographic findings were usually unsuspected. In 6 of the 107 cases the common, external and internal carotid arteries were found to be thrombosed on one side when they were exposed. In 2 cases there was bilateral occlusion of the common carotid and in 2 cases, bilateral occlusion of the internal carotid. In the remaining 97 cases, the thrombosis involved only the internal carotid artery. In these cases the radiopaque dye filled only the external carotid vessels, which frequently seemed to be dilated. The internal carotid was found to be occluded at one of two sites—either within several centimeters of the bifurcation or at the carotid siphon. With occlusions at the former site, a stump or short segment of the internal carotid artery was visualized by angiography. In 16 cases the site of occlusion was at the siphon. In 4 of these a complete occlusion was not demonstrated, but the vessel in the region of the siphon was markedly narrowed and irregular, suggesting canalization of a thrombus.

Sugar, Webster, and Gurdjian[33] reported an interesting observation in one patient. At the time of the first angiogram, the internal carotid artery was found to be occluded at the siphon. Two years later the point of occlusion was found to be several centimeters distal to the carotid bifurcation. An arteriographic characteristic is the filling of the anterior communicating

and anterior cerebral arteries of the occluded side by angiography performed on the normal side. Rarely the middle cerebral artery is filled by this technique. This demonstration of anterior collateral circulation probably accounts for the fact that aphasia and paralysis of the arm are usually the most severe neurological defects. Bilateral angiography was performed in 29 cases. In 1 of these cases,[29] the patient died 1 hour after angiography. There is, then, danger in performing carotid angiography on the side opposite an occluded vessel.*

## VENTRICULOGRAPHY

Ventriculography or pneumoencephalography was performed in almost one half the cases and almost uniformly demonstrated dilatation of the ventricles, frequently more on the side of the thrombosis. Air studies were done in 4 of our patients. In 1 case the pneumoencephalograms were normal but in 3 there was dilatation of the ventricle on the side of the occluded vessel.

## ETIOLOGY

No single etiologic factor has been determined. Syphilis probably plays little role, for in only 2 cases was a positive serological reaction reported. The blood pressure has usually been normal and in only 10 cases was it over 180 mm. of mercury. In 13 cases there was a history of head injury, usually months or years preceding the onset of symptoms. In 1 case the patient had been hit on the head the day before the onset of his illness.

Several authors have suggested the possibility of retrograde thrombosis from an intracranial aneurysm. There was some evidence to support this. In the case reported by James,[16] there was bloody spinal fluid and, through a burr hole, 15 cc. of dark clot were evacuated from the temporal lobe. Le Beau[22] also suspected aneurysm in a patient who had only headache and a 3rd and 4th nerve paralysis. There have been 3 other cases reported of involvement of the 5th nerve with ptosis in which one might suspect the presence of an aneurysm. In 1 of our cases the patient had a sudden onset of his illness and a bloody spinal fluid. There have been instances reported in which at autopsy an aneurysm was found occluding the internal carotid. Saphir[27] has described 3 such cases of arteriosclerotic serpentine aneurysm of the internal carotid in the cavernous sinus. While an aneurysm has not been demonstrated in any of the 107 cases, it is conceivable that it might be an etiologic factor in some instances.

The suggestion has also been made that the thrombosis of the carotid artery is the result of retrograde extension of a thrombus originating in one of the cerebral vessels. In none of the 9 cases in which autopsy was performed, however, was this hypothesis confirmed. Fisher[12] recently reported the autopsy findings in 4 patients suspected of having cerebrovascular disease in

* In the discussion of this paper at the meeting of the Harvey Cushing Society, 3 other instances of death following angiography of the non-occluded carotid were described. If occlusion of the carotid on one side is demonstrated, angiography of the opposite side is a hazardous procedure.

whom the site of the thrombosis was not in the cerebral vessels but in the internal carotid artery.

The two most common factors appear to be arteriosclerosis and thrombo-angiitis obliterans. The sites of occlusion of the internal carotid, the carotid bifurcation and the carotid siphon, are points of predilection for atheromatous changes, according to Dow.[10] In a study of 55 consecutive autopsies Keele[17] found atheromatous changes in the carotid sinus in 50 cases.

Cerebral thrombo-angiitis obliterans has been reported to be associated at autopsy with thrombosis of one internal carotid artery. Antoni[3] described 2 such cases and mentioned a 3rd, the case of Andrell (cf. Table 1). Davis and Perret[9] also reported a similar case. In 4 of the reported cases described in Table 1 there was evidence of peripheral arterial disease with intermittent claudication and absence of pulsation in the arteries of the legs.

In 22 cases a segment of the vessel excised at operation was examined histologically. In 7 cases a diagnosis of thrombo-angiitis obliterans was made and in 9 the vessel was found to be arteriosclerotic; in 2 there was thickening of the intima with some perivascular round-cell infiltration and in 2 others only a thickened intima was described. In 1 case the intima was said to be normal and the adventitia and media were thickened. One is simply described as showing no inflammatory reaction. In an additional 9 cases, examination was made post mortem. In 2 a diagnosis of cerebral thrombo-angiitis obliterans was made, and in 1, thrombo-angiitis of the internal carotid. Arteriosclerosis was found in 2 cases and in 2 others only cerebral softening was described. The autopsy findings were not given in 2 of the cases.

## TREATMENT

Most of the patients had no specific treatment. However, two forms of therapy have been tried, cervical sympathectomy and arteriectomy. In 4 cases a cervical sympathectomy was done—2 with no improvement, 1 with slight improvement and 1 patient died in 2 days. Two of the 4 patients who had a cervical sympathectomy are from our series—1 with no improvement and 1 with only slight improvement.

Several authors (Moniz,[25] Riechert,[26] Sorgo,[31] and Andrell[2]) have stated that the presence of the thrombosed vessel might result in a reflex spasm of the smaller cerebral vessels. It has been suggested that this might account for the transient nature of the symptoms. Based on this reasoning, excision of the thrombosed vessel has been carried out in 28 cases. In 7 there was improvement, in 6 no change, and in 15 the results were not reported. In 2 cases a combined cervical sympathectomy and vessel excision was performed without improvement. In 1 case a periarterial stripping was done, following which the patient was worse. A superior cervical ganglionectomy and excision of the carotid bifurcation was then performed without improvement. Barré,[4,5] Wolfe,[41] and Erikson,[11] have all reported cases in which there was microscopic evidence of recanalization of an old thrombus with rethrombosis. Because of the possibility of recanalization occurring, the advisability of

resecting the vessel has been questioned. Several authors have suggested anticoagulant therapy, but only 1 instance of its use has been reported.

## PROGNOSIS

Once the diagnosis has been made, the prognosis for improvement is not particularly hopeful. Thirteen of the reported patients died within several months. In 53 of the cases, no mention was made of the patient's course and in 15 there was no change. Only about 25 per cent showed any improvement with or without treatment. There seems to be no correlation between the degree of improvement and the type of onset. Two of our patients had sufficient improvement to return to work.

## COMMENT

This review concerns only those cases diagnosed by arteriography. There have, of course, been cases diagnosed without the aid of arteriography. An example of this is the group of cases described in Walsh's *Clinical Neuro-ophthalmology*,[39] in which the diagnosis was made on the basis of the ophthalmological and associated neurological disturbances. The cases reported by King and Langworthy[18] are of this type. In patients with visual symptoms indicating involvement of the ophthalmic artery, the diagnosis may be apparent. In 65 of the 107 cases, however, there were no visual signs or symptoms and in only 11 were there optic atrophy and blindness. Palpation of the neck may reveal the absence of pulsation of the internal carotid artery, or more easily, of the common carotid artery. The finding of this physical sign, however, is seldom mentioned in the recorded histories. If the condition is kept in mind, this physical finding may more commonly suggest the diagnosis prior to the performance of angiography. It is probably reasonable to say that without the use of angiography, a large percentage of these lesions would not have been diagnosed correctly. Fisher[12] recently reported that in 200 cases of cerebrovascular disease in which the brains were examined, not a single case of thrombosis of the middle cerebral artery was found, although the diagnosis had been made often clinically.

The visualization of only the external carotid artery in an angiogram is not sufficient evidence to make the diagnosis of thrombosis of the internal carotid. This is a technical error which occurs occasionally, and subsequent angiography in the same patient may demonstrate the internal carotid system. In patients in whom the diagnosis is suspected, it is necessary for the roentgenograms to be taken so that the common carotid and region of the carotid bifurcation in the neck are visualized. In cases in which only the external carotid was seen in the angiograms, the diagnosis has also been made by a subsequent exposure of the carotid vessels in the neck.

As stated by Moniz,[25] spontaneous thrombosis of the internal carotid artery is probably much more common than has been thought. Many patients are suspected of having a brain tumor, aneurysm, or some vague cerebrovascular accident. In this group of patients, the use of angiography greatly assists in coming to a correct diagnosis.

## SUMMARY

Six cases of spontaneous thrombosis of the internal carotid artery diagnosed by angiography are described. One hundred and one similar cases have been found in the literature. The significant aspects of the histories of these patients are reviewed and tabulated. The etiology, treatment and angiographic characteristics are described.


## REFERENCES


1. Ameli, N. O., and Ashby, D. W. Non-traumatic thrombosis of the carotid artery. *Lancet*, 1949, *2:* 1078–1082.
2. Andrell, P. O. Thrombosis of the internal carotid artery. A clinical study of nine cases diagnosed by arteriography. *Acta med. scand.*, 1943, *114:* 336–372.
3. Antoni, N. Buerger's disease, thrombo-angiitis obliterans, in the brain. Report of three (four) cases. *Acta med. scand.*, 1941, *108:* 502–528.
4. Barré, J.-A., Philippidès, and Isch, F. Thrombose de la carotide interne. Étude clinique, artério et encéphalographique. *Rev. neurol.*, 1947, *79:* 442–444.
5. Barré, J.-A., Philippidès, and Isch, F. Thrombose de la carotide interne (2e cas). Étude clinique pré et postopératoire. *Rev. neurol.*, 1947, *79:* 662–664.
6. Barré, Rohmer, and Isch. Nouveau cas de thrombose de la carotide interne. Essai de synthèse clinique. *Pr. med.*, 1950, *58:* 525.
7. Budínová-Smělá, J., Lhotka, J., and Marx, F. Thrombosis arteriae carotis internae. *Čas. Lék. čes.*, 1949, *88:* 93–98.
8. Chao, W. H., Kwan, S. T., Lyman, R. S., and Loucks, H. H. Thrombosis of the left internal carotid artery. *Arch. Surg., Chicago*, 1938, *37*, 100–111.
9. Davis, L., and Perret, G. Cerebral thrombo-angiitis obliterans. *Brit. J. Surg.*, 1947, *34:* 307–313
10. Dow, D. R. The incidence of arterio-sclerosis in the arteries of the body. *Brit. med. J.*, 1925, *2* 162–163.
11. Erikson, S. Über Arteriographie bei Thrombose in der Carotis interna. *Acta radiol., Stockh.*, 1943, *24:* 392–402.
12. Fisher, M. Occlusion of the internal carotid artery. *Arch. Neurol. Psychiat., Chicago*, 1951, *65:* 346–377.
13. Frövig, A. G. Bilateral obliteration of the common carotid artery. Thromboangiitis obliterans? A contribution to the clinical study of obliteration of the carotids and to the elucidation of the cerebral vascular circulation. *Acta psychiat., Kbh.*, 1946, suppl. 39, 79 pp.
14. Gladston, M., Govons, S., Wortis, S. B., Steele, J. M., and Taylor, H. K. Thrombosis of the common, internal and external carotid arteries. A report of two cases with a review of the literature. *Arch. intern. Med.*, 1941, *67:* 1162–1176.
15. Govons, S. R., and Grant, F. C. Arteriographic visualization of cerebrovascular lesions. *Arch. Neurol. Psychiat., Chicago*, 1946, *55:* 600–618.
16. James, T. G. I. Thrombosis of the internal carotid artery. *Brit. med. J.*, 1949, *2:* 1264–1267.
17. Keele, C. A. Pathological changes in the carotid sinus and their relation to hypertension. *Quart. J. Med.*, 1933, n.s. *2:* 213–220.
18. King, A. B., and Langworthy, O. R. Neurologic symptoms following extensive occlusion of the common or internal carotid artery. *Arch. Neurol. Psychiat., Chicago*, 1941, *46:* 835–842.
19. Krayenbühl, H. Zur Diagnostik und chirurgischen Therapie der zerebralen Erscheinungen bei der Endangiitis obliterans v. Winiwarter-Buerger. *Schweiz. med. Wschr.*, 1945, *75:* 1025–1029.
20. Krayenbühl, H., and Weber, G. Die Thrombose der Arteria carotis interna and ihre Beziehung zur Endangiitis obliterans v. Winiwarter-Buerger. *Helv. med. Acta*, 1944, *11:* 289–333.
21. Krieg, W. Kollateralkreislaufentwicklung bei Durchblutungsstörungen des Gehirns im arteriographischen Bild. Eine pathogenetische Betrachtung. *Zbl. Chir.*, 1939, *66:* 562–578; 681–699.
22. Le Beau, J., Mahoudeau, D., Daum, S., and Tavernier, J.-B. Ophtalmoplégie unilatérale; seul signe d'une thrombose de la carotide interne décelée par l'artériographie. *Bull. Soc. méd. hôp. Paris*, 1949, *65:* 509–511.
23. Milletti, M. Does a clinical syndrome of primitive thrombose of the internal carotid at the neck exist? *Acta Neurochir.*, 1950, *1:* 196–231.
24. Moniz, E. Tromboses da carótida interna e artérias suas derivadas. *Med. (A) contemp.*, 1947, *65:* 111–132.

25. Moniz, E., Lima, A., and de Lacerda, R. Hémiplégies par thrombose de la carotide interne. *Pr. med.*, 1937, *45:* 977–980.
26. Riechert, T. Die Arteriographie der Hirngefässe bei einseitigem Verschluss der Carotis interna. *Nervenarzt*, 1938, *11:* 290–297.
27. Saphir, O. Serpentine aneurysm of the internal carotid artery with resulting encephalomalacia and cerebral hemorrhage. *Arch. Path.*, 1935, *20:* 36–45.
28. Shimidzu, K. Beiträge zur Arteriographie des Gehirns—einfache percutane Methode. *Arch. klin. Chir.*, 1937, *188:* 295–316.
29. Siegert, P. Die ursächliche Bedeutung einer Verkalkung oder Thrombose der Carotis interna für Funktionsstörungen des Auges. *v. Graefes Arch. Ophthal.*, 1938, *138:* 798–844.
30. Sjöqvist, O. Über intrakranielle Aneurysmen der Arteria carotis und deren Beziehung zur ophthalmoplegischen Migräne. *Nervenarzt*, 1936, *9:* 233–241.
31. Sorgo, W. Über den durch Gefässprozesse bedingten Verschluss der Art. carotis interna. *Zbl. Neurochir.*, 1939, *4:* 161–179.
32. Sponer, E. Beitrag zu dem durch Gefässveränderungen bedingten Verschluss der Arteria carotis interna. *Beitr. klin. Chir.*, 1942, *172:* 481–495.
33. Sugar, H. S., Webster, J. E., and Gurdjian, E. S. Ophthalmologic findings in spontaneous thrombosis of the carotid arteries. *Arch. Ophthal., N. Y.*, 1950, *44:* 823–832.
34. Takahashi, K. Die percutane Arteriographie der Arteria vertebralis und ihrer Versorgungsgebiete. *Arch. Psychiat. Nervenkr.*, 1940, *111:* 373–379.
35. Taptas, J. N., and Pecker, J. Les thromboses de la carotide interne et de ses branches. *Rev. neurol.*, 1948, *80:* 3–16.
36. Tölle, R. Doppelseitige Thrombose der Art. carotis interna. *Zbl. Chir.*, 1942, *69:* 219–226.
37. Torkildsen, A., and Koppang, K. Notes on the collateral cerebral circulation as demonstrated by carotid angiography. *J. Neurosurg.*, 1951, *8:* 269–278.
38. Trotot, R. P. Hémiplégie avec aphasie par thrombose de la carotide interne. *Rev. neurol.*, 1944, *76:* 254.
39. Walsh, F. B. Clinical neuro-ophthalmology. *Baltimore: Williams & Wilkins Co.*, 1947, xx, 1532 pp.
40. Webster, J. E., Dolgoff, S., and Gurdjian, E. S. Spontaneous thrombosis of the carotid arteries in the neck. *Arch. Neurol. Psychiat., Chicago*, 1950, *63:* 942–953.
41. Wolfe, H. R. I. Unexplained thrombosis of the internal carotid artery. *Lancet*, 1948, *2:* 567–569.

# ARTERIOGRAPHIC DEMONSTRATION OF SPASM OF THE INTRACRANIAL ARTERIES

## WITH SPECIAL REFERENCE TO SACCULAR ARTERIAL ANEURISMS*

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THE percutaneous method of puncturing the carotid artery allows cerebral angiography to be performed on repeated occasions in the same patient. The cerebral arteries thus visualized with the same technic on different occasions generally are identical but sometimes differ strikingly in caliber. When the artery has the smaller caliber it is said to be in *arterial spasm*. It is the purpose of this paper to present our observations of such spasm and to indicate its possible significance.

### MATERIALS AND METHODS

For this study there were available about 400 groups of angiograms made on 350 patients. The patients were mostly adults and suffered from a variety of medical and surgical neurologic disorders. We have found only 12 instances, among 10 of these cases, which have met our criteria of arteriographically demonstrated spasm. This study is devoted to the intracranial portion of the internal carotid artery, its subdivisions, the anterior and middle cerebral arteries and their main branches. It is concerned only with vessels of at least 1.5 mm. in internal diameter.

Arterial spasm can be definitely recognized arteriographically when a vessel is of larger caliber in a subsequent angiogram than was demonstrated at a previous study made under identical conditions. This study is concerned with spasm of only moderate degree, rather than with maximal spasm or total occlusion of the vessel, which obviously cannot be recognized arteriographically. Minimal spasm, with alterations of caliber of less than 0.5 mm., will not be considered because of the difficulties involved in precise measurement.

Marked spasm slows the blood stream. In such cases arteriograms with routine timing show filling of only the proximal portion of the intracranial arteries. Repeating the arteriogram with delayed timing of the exposure (by $\frac{1}{2}$ to 5 seconds) will show full arterial filling. When spasm is relieved the velocity of blood flow becomes normal as demonstrated by full arterial filling with routine timing.

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## PSEUDOSPASM AND SOME OTHER SOURCES OF ERRONEOUS INTERPRETATION

*Nonfilling of a Length of Artery.* During the carotid injection of diodrast®, there is probably a slight increase of intra-arterial pressure. However, the instant the injection is over, the pressure in the carotid artery cephalad from the needle becomes *less* than normal because of the mere presence of the needle within the arterial wall and its lumen. At this instant blood rushes into the injected vessels from the other carotid and from the basilar

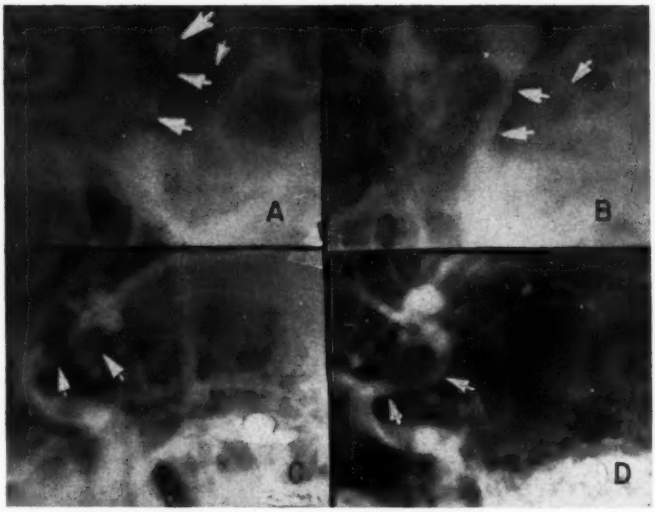


FIG. 1. *Case 1.* Aneurism at bifurcation of left internal carotid artery. Spontaneous subarachnoid hemorrhage Sept. 21, 1950. Arteriograms after left carotid injection. Chamberlain-Towne views: (A) On October 2 with spasm of aneurism itself and adjacent arteries at bifurcation of left internal carotid artery. (B) On November 3 without spasm. Left lateral views: C as A; D as B. Arrows point to aneurism, internal carotid and middle cerebral arteries.

artery via the circle of Willis. An exposure made at this moment reveals dye in the proximal part of the injected carotid artery and the distal portions of the anterior and middle cerebral arteries, whereas the circle of Willis and the adjacent portions of these vessels are not visualized. This appearance, due entirely to a slight delay in exposure of the arteriogram, has been called *pseudospasm*.[3]

*Localized Narrowing of Vessels from Causes other than Spasm.* The angiographic appearance of cerebral *arteriosclerosis* is most often that of unusually wide and tortuous vessels. Nevertheless, localized arterial narrowings may be due to arteriosclerosis. These narrowings may appear not only as obvious plaques with almost rectangular edges, but also as gradual tapers similar to the narrowing of spasm. Furthermore, a given vessel may be *congenitally* narrow. Accordingly we have required a variation in caliber of

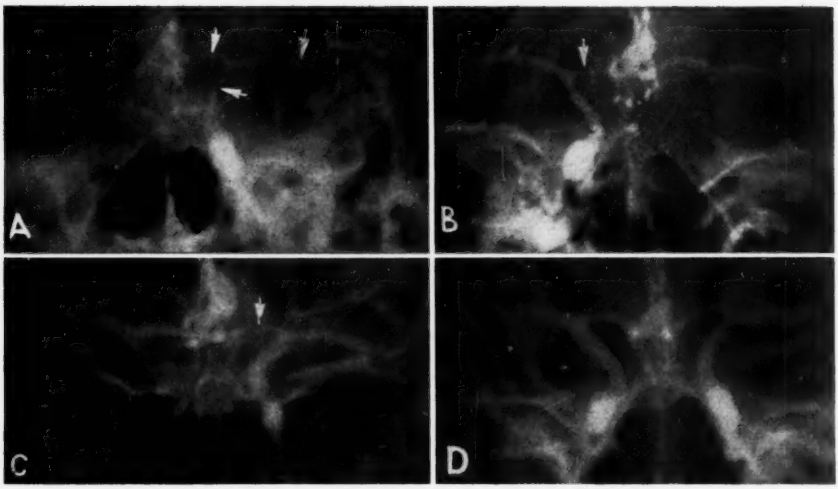


FIG. 2. *Case 2.* Aneurism of anterior communicating artery. Subarachnoid hemorrhage July 21, 1950 and Sept. 21, 1950. Chamberlain-Towne projection of arteriograms. (A) Left carotid injection; spasm at bifurcation of left internal carotid artery, July 28. (B) Right carotid injection; spasm at bifurcation of right internal carotid artery. (C) Left carotid injection; spasm of left anterior cerebral artery, September 29. Aneurism larger than in B. (D) Left carotid injection after intravenous injection of papaverine hydrochloride and inhalation of amyl nitrite, October 31. No spasm in anterior part of circle of Willis. Fundus of aneurism thrombosed. This was confirmed at postmortem examination. Arrows point to spastic vessels. Compare with Fig. 3.

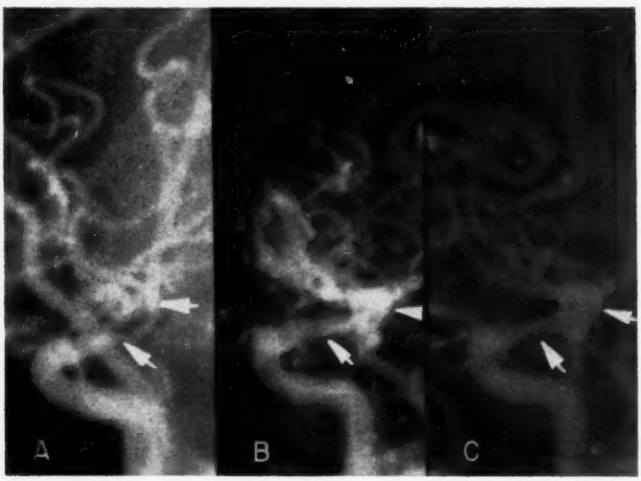


FIG. 3. *Case 2.* Aneurism of anterior communicating artery. Lateral arteriograms made after left carotid injection on (A) July 28, (B) September 29, (C) October 31. Note the variation in caliber at the terminal portion of the internal carotid artery, minimal in July. The aneurism is best seen in B. Compare with Fig. 2 A, C, D. Arrows point to internal carotid artery.

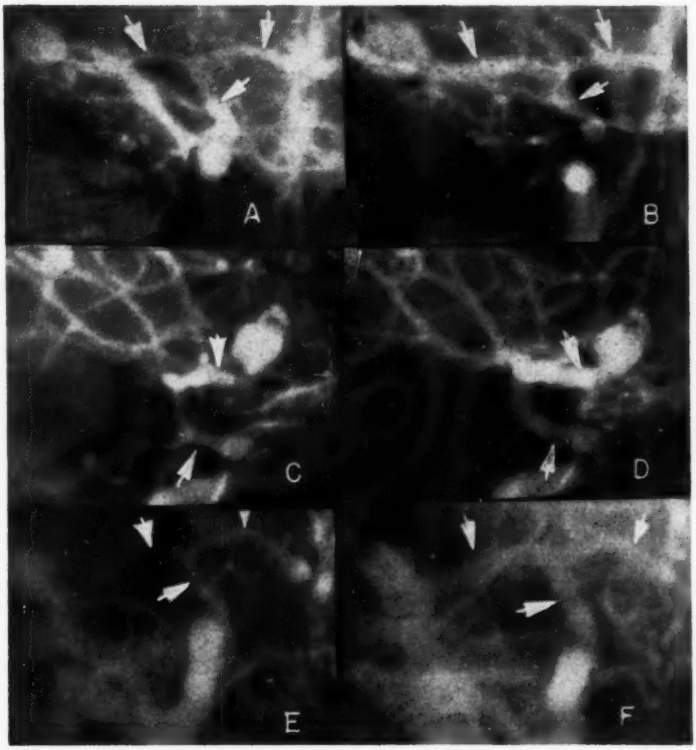


FIG. 4. *Case 3.* Aneurism at bifurcation of right middle cerebral artery. Spontaneous subarachnoid hemorrhage Jan. 4, 1951. Arteriograms made after right carotid injections. Anteroposterior views: (A) January 15; (B) March 20. Lateral views: (C) January 15; (D) March 20; Chamberlain-Towne views: (E) January 15; (F) March 20. All films show the aneurism at the bifurcation of the right middle cerebral artery. The three views made in January all show constriction of the right internal carotid artery, its terminal branches and the aneurism itself. This spasm is absent from the films made in March.

the same vessel as seen on two different films before accepting it as a definite example of spasm.

## CASES OF ARTERIOGRAPHICALLY PROVED SPASM

There were 6 cases of *untreated* saccular arterial aneurism of or near the anterior part of the circle of Willis in which spasm was visualized. In each case there had been spontaneous subarachnoid hemorrhage; twice in Case 2. In 5 cases spasm was present in earlier films and absent from later films; in 1 case the reverse. These 6 cases were selected out of a total of 29 cases where aneurisms had been demonstrated arteriographically. In 18 of these cases there was no evidence of arterial narrowing in the angiograms. In the remaining 5 cases spasm was suggested by narrowed vessels at a single angio-

graphic session but it remains unproved since comparative films are not available.

There were 2 cases of postoperative narrowing of cerebral vessels following carotid ligation in the neck. In one there had been total ligation and in the other (Case 5) partial ligation. We have had 2 additional cases of carotid ligation in the neck (1 total, 1 partial) where postoperative films demonstrated no vasoconstriction when compared with pre-operative. In our cases

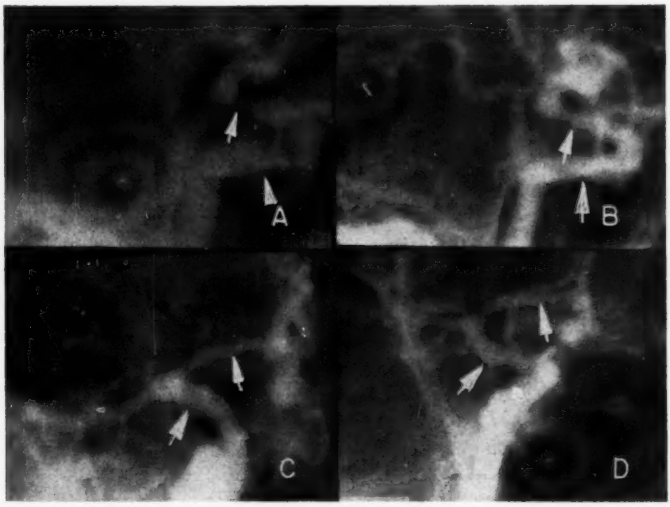


FIG. 5. *Case 4.* Aneurism arising at junction of anterior communicating and right anterior cerebral arteries. Spontaneous subarachnoid hemorrhage March 9, 1951. Arteriograms made after right carotid injection, all on the same date. No drugs were administered during angiography. Lateral views: (A) showing practically no spasm; (B) showing marked narrowing of the intradural and subarachnoid course of the internal carotid artery; (C) Chamberlain-Towne view without vasoconstriction; (D) view of right optic foramen showing spasm of the terminal portion of the internal carotid artery, the anterior cerebral artery and the aneurism itself.

of partial ligation the same carotid artery was injected. In those of total ligation the contralateral carotid was injected and the question of narrowing was determined in the middle cerebral artery of the ligated side.

Generally the spasm was maximal in degree at the site of the lesion and extended along adjacent arteries for 1 or more cm. in milder degree. Often the spasm was marked intracranially but was absent in the internal carotid artery proximal to the anterior clinoid process.

In most cases, the difference in caliber was seen by comparing arteriograms made on different days, usually several weeks apart. Except for Case 4 and the influence of drugs, all arteriograms made at the same session showed the same degree of spasm.

## DISCUSSION

*Physical and Physiological Factors in Production of Spasm.* Any change in caliber of the arteries due to the presence of the needle, the pharmacodynamic effect of the dye and the minimal rise of intracarotid pressure from the injection of the dye would have been relatively constant for all cases.

Uncontrolled variables include chemical constituents of the blood such as the circulating hormones and carbon dioxide. However, such factors could not reasonably be expected in themselves to cause *localized* or *unilateral* changes in caliber of the vessels. We emphasize the role of the local factor in most of our cases, where all arteriograms made in various projections *on the same occasion* showed the same localization and degree of spasm.

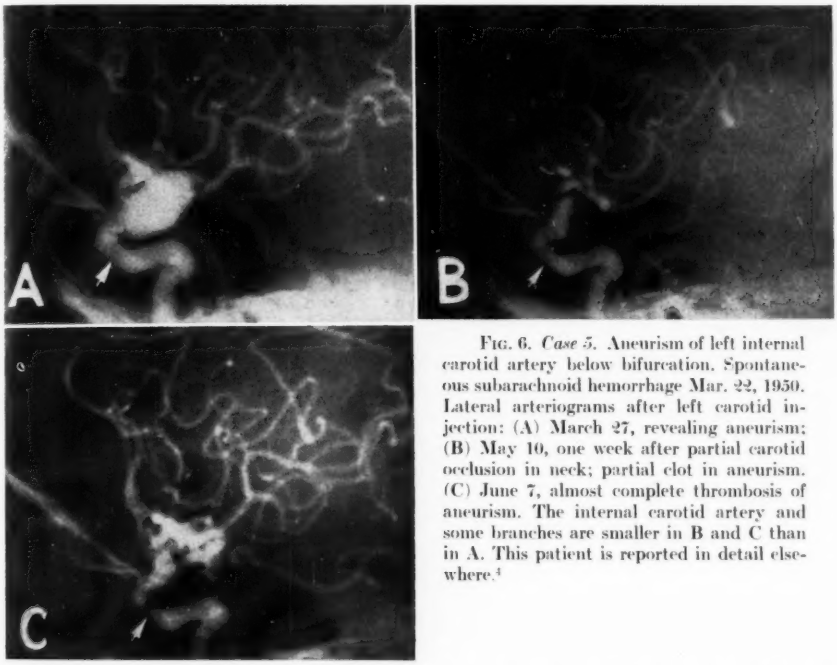


FIG. 6. *Case 5.* Aneurism of left internal carotid artery below bifurcation. Spontaneous subarachnoid hemorrhage Mar. 22, 1950. Lateral arteriograms after left carotid injection: (A) March 27, revealing aneurism; (B) May 10, one week after partial carotid occlusion in neck; partial clot in aneurism. (C) June 7, almost complete thrombosis of aneurism. The internal carotid artery and some branches are smaller in B and C than in A. This patient is reported in detail elsewhere.[4]

*The Nature of Arterial Spasm.* Strange as it may seem, the normal function of the smooth muscle in the walls of the larger arteries has never been elucidated. However, under certain abnormal circumstances, the lumen of the artery narrows and the artery is said to be in spasm.[6] In 20 monkeys a clip was placed on the middle cerebral artery to occlude the vessel. In 10 of these cases spasm appeared in the internal carotid artery and lasted from 1 to 10 minutes.[5] In a case of suprasellar cyst in a child where the frontal lobe was elevated, one of us (A.E.) has seen severe spasm of the internal

carotid artery, apparently as the result of traction. Dr. Robert Bassett on two occasions has gently touched the internal carotid artery in its subarachnoid course. This procedure produced spasm of the artery and allowed him to apply a metal clip which previously had been too small.[1] It is not known for certain whether this spasm is due to the muscular or the elastic tissue or to both, or what factors determine the degree or duration of the contraction.

The linear extent of the spasm may vary from 1 to several cm. This is made understandable by recalling that both muscular coats of an artery are basically spiral. The so-called longitudinal muscular coat is a long spiral and the so-called transverse muscular coat is a short spiral. The duration of the spasm may be brief or more prolonged. It lasts at least a few months, in some cases following ligation or the "near miss" of a high velocity missile.[2]

In general, the stimulus producing spasm seems to be *traction* on the artery. It may be longitudinal or lateral traction, the application of a ligature or metallic clip, or the impaction of a solid embolus. The production of arterial spasm by a fractured bone is presumably of the first type, by a high velocity missile of the second.[2] We have seen spasm most frequently in cases of aneurism and its presence suggests traction on the vessel wall.

Other conditions where we have seen narrowing of the anterior and/or middle cerebral arteries strongly suggestive of spasm are: acute severe internal hydrocephalus, severe cerebral edema, intracerebral hemorrhage, malignant hypertension without arteriosclerosis, and the syndrome of "cerebral collapse" (presumably due to oligemia and predisposing to subdural hematoma). Spasm in the femoral artery has been produced experimentally by acute severe arterial hypotension.[6] Spasm probably occurs in association with arteriosclerosis and with thrombosis of the internal carotid artery and its larger branches. The mechanism of spasm from intrinsic lesions of the arterial wall is unknown.

*The Role of Spasm in Cases of Aneurism.* It is probable that arterial spasm plays an important role following spontaneous rupture of saccular aneurisms of or near the circle of Willis. If there were no reactive contractile force in the wall of the aneurism or adjacent artery, the original pin-point leak would be followed by a large tear. Then, instead of only a few, all of these patients would die from the first hemorrhage. According to this hypothesis, the cases that are immediately fatal are those where the arteries do not go into spasm.

We have reviewed all our cases of angiographically proved intracranial arterial aneurisms with subarachnoid hemorrhage and without surgical treatment. There were 12 instances of hemorrhage (among 11 patients) where arteriograms were made 23 days or earlier after the hemorrhage. In each case except 1 there was demonstrable arterial narrowing (proved to be spasm in 7 instances by later normal angiograms). On the other hand, in another group of 10 cases where arteriograms were made 26 days or longer after the hemorrhage, there was no evidence of spasm. These data seem to support the suggestion that arterial spasm occurs after rupture of an intra-

cranial aneurism. Persistence of vasoconstriction may indicate continued or additional stretch of the aneurismal wall. Certainly spasm disappeared after a few weeks in those of our patients who survived.

Furthermore, spasm may play a considerable role in the production of intra-aneurismal thrombosis, as in Cases 2 and 4. Finally, excessive spasm may produce unfavorable effects by impairing the circulation of the brain in the area nourished by the affected artery.

On the other hand, we have had 3 cases of large unruptured aneurisms of the circle of Willis, all without evidence of arterial constriction.

## SUMMARY

Spasm of the larger intracranial arteries (internal diameter at least 1.5 mm.) has been demonstrated in 12 instances among 10 cases by means of comparative arteriograms. The affected vessels were the internal carotid, anterior cerebral, and middle cerebral arteries and their branches.

Seven examples of spasm occurred in 6 cases of saccular arterial aneurism of or near the circle of Willis. These were selected from a total group of 29 cases of angiographically demonstrated aneurisms that had recently ruptured. Arteriograms made soon (23 days or earlier) after a subarachnoid hemorrhage from such an aneurism generally revealed arterial spasm; those made later (26 days or more) revealed none.

Other instances of spasm were associated with: total or partial ligation (1 each) of the carotid artery in the neck, postoperative astrocytoma, localized intracerebral hemorrhage and edema, and severe intrinsic lesion of the arteries.

The common element in the production of spasm in all cases seemed to be abrupt traction on the arterial wall. Usually the spasm was maximal at the lesion but extended several cm. along adjacent arteries in lesser degree. Except for Case 4, all arteriograms made at the same session revealed the same location and degree of spasm.

## REFERENCES

1. Bassett, R. Discussion of this paper at meeting of Harvey Cushing Society, Hollywood, Florida, April 26, 1951.
2. Ecker, A. Spasm of the internal carotid artery. *J. Neurosurg.*, 1945, *2:* 479–484.
3. Ecker, A. The normal cerebral angiogram. *Springfield, Ill.: Charles C Thomas*, 1951, xx, 190 pp.
4. Ecker, A., and Riemenschneider, P. Deliberate thrombosis of intracranial arterial aneurism by partial occlusion of the carotid artery with arteriographic control. Preliminary report of a case. *J. Neurosurg.*, 1951, *8:* 348–353.
5. Harvey, J., and Rasmussen, T. Occlusion of the middle cerebral artery. An experimental study. *Arch. Neurol. Psychiat., Chicago*, 1951, *66:* 20–29.
6. Kinmonth, J. B., Simeone, F. A., and Perlow, V. Factors affecting the diameter of large arteries with particular reference to traumatic spasm. *Surgery*, 1949, *26:* 452–471.

# CASE REPORTS

## HEMANGIOMA OF THE SPINAL CANAL AND PREGNANCY

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Vascular tumors of the spine and spinal cord are not uncommon, but they have rarely been noted as a complication related to pregnancy. Glaser[7] reported a case of angiosarcoma of the cord in which progressive paraplegia developed during the last half of pregnancy. Following delivery there was a brief interval of improvement prior to gradual decline and death. Balado and Morea[1] found an extradural angiolipoma at autopsy on a woman whose seventh pregnancy had been characterized by paraplegia with improvement after delivery. Permanent paralysis developed during her eighth pregnancy, culminating in death. Temporary improvement of spinal cord signs following delivery was noted in 2 cases of hemangioma reported by Delmas-Marsalet[4] and Guthkelch.[8] The former lesion was proved at operation; the latter was found at autopsy. The clinical manifestations in a case of hemangioma recently observed by us conform closely to the previous descriptions.

### CASE REPORT

A well-circumscribed extradural hemangioma of the upper dorsal segments is reported. The initial clinical manifestations appeared in the last trimester of the ninth pregnancy of a 36-year-old woman; there was subsequent remission of symptoms and signs during the immediate postpartum period. Cessation of that improvement led to operation and complete removal of the tumor with a remarkable recovery.

#49-42612. W.M.S., a 36-year-old female, para viii, gravida ix, was admitted to the Obstetrical Service of the Homer G. Phillips City Hospital, Nov. 13, 1949, during the last month of her pregnancy. Gestation had been unremarkable until 1 month before admission, when she noted the gradual onset of weakness, paresthesias, coldness, and impaired sensation in both lower extremities, more severe on the right. Subsequently, she complained of dull thoracic back ache and a girdle sensation about her abdomen. There developed increased urinary frequency. There was no history of similar complications associated with any of her previous pregnancies. A primary syphilitic lesion had been found in 1933, with a positive serological test. Intensive antiluetic therapy had been given, resulting in persistently negative serology from 1939 to her recent hospitalization.

*Examination.* She was a well-developed, well-nourished young colored female in approximately the 34th week of a normal pregnancy. There was spastic paraplegia, with considerably greater involvement on the right. All tendon reflexes in the lower extremities were increased. The right knee and ankle jerks were more active than those on the left. Bilateral ankle clonus was present, but was more sustained and active on the right. Patellar clonus was unsustained bilaterally. Marked extensor toe signs were elicited on the right. Those on the left were equivocal. Abdominal reflexes were absent. Sensory examination showed a strongly suggestive level at L-1, involving particularly pin prick and temperature appreciation. Deep sensation

was not significantly diminished. Both lower extremities were cold to palpation. Three days after lumbar puncture, examination demonstrated a progression of the sensory level to the 3rd thoracic dermatome, and mild but definite decrease of position, motion and vibratory sense in the lower extremities.

CFS pressure was 240 mm. water. Fluid was clear and colorless and contained no cells; total protein was 91 mg. per cent with positive Pandy; Wassermann and colloidal gold tests were negative. Manometric studies gave the impression of an incomplete block. Roentgenograms of the thoracic, lumbar, and sacral spine were negative. The interpedicular distances were normal. Blood and urine were normal.

*Course.* On Nov. 29, 1949, the patient gave birth to a normal $6\frac{1}{2}$ pound infant after an uncomplicated 7-hour delivery. The postpartum recovery was entirely satisfactory. Regression in the sensory level rapidly followed. There was considerable return of strength in the right lower extremity. She was discharged on Dec. 10, 1949, returning home for convalescence. However, she did not continue to improve and was hospitalized on Jan. 28, 1950 for reevaluation. Shortly before, she had noted incontinence of urine.

*Examination on Readmission.* The sensory level was again at D-3, without sacral sparing and dissociation of sensation noted during her previous hospitalization. A sweating level corresponded to the sensory loss. Motor signs were more prominent, with a paraplegia in extension. Again, complete spine studies by x-ray showed no evidence of bony changes. Lumbar puncture disclosed an initial pressure of 150 mm. water, and complete block on manometrics. Subsequent myelography indicated a failure of pantopaque to flow beyond the T-3 level.

*Operation.* With a tentative diagnosis of a slowly growing benign extramedullary tumor, probably a vascular meningioma, dorsal laminectomy was performed by one of us (GER) on Feb. 23, 1950.

Surgical removal of the lamina of the 2nd, 3rd and 4th thoracic vertebrae disclosed a highly vascular epidural space containing a dark-red tumor mass measuring $3 \times 1\frac{1}{2}$ cm. The lesion was discrete, entirely extradural, and partially encompassed the dorsal surface of the dural sac, extending more to the left than to the right. The mass was removed in toto.

*Histopathological Diagnosis:* Hemangioma (Fig. 1).

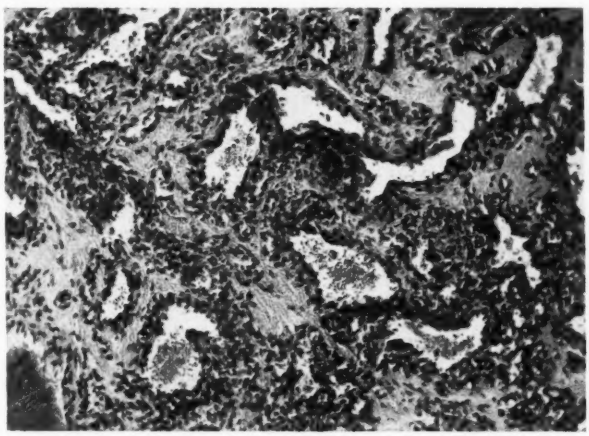

FIG. 1. Extradural hemangioma of the spinal canal from case W.M.S. Hematoxylin and eosin stain, ×108.

The *postoperative course* was entirely uncomplicated and during the latter part of the first week of recovery, motor and sensory function definitely improved. Subsequent return of

neurological function was rapid and the patient left the hospital April 28, 1950, ambulatory with the aid of a cane, and without any evidence of sensory loss. Several weeks later, completely normal activity was possible without any mechanical aids. Deep tendon reflexes were normal, and pathological toe signs were absent.

## DISCUSSION

In the case we have just presented, as in cases previously reported, symptoms of an intraspinal vascular lesion developed during the last half of pregnancy, and improved temporarily following delivery.

In explaining the influence that pregnancy may have upon hemangiomas of the spinal canal, two possibilities must be considered: accelerated neoplasia and vascular changes due to obstruction or to endocrine influences of pregnancy. The relationship between the highly malignant chorioepithelioma and hydatidiform mole is well established. On the other hand, the direct effect of pregnancy upon behavior of other neoplastic lesions, especially tumors of the nervous system, is not clear. In neurofibromatosis increased pigmentation may occur during pregnancy, with later diminution during the puerperium. The same observations have been noted in epulides. Isolated reports suggest that acoustic neurinoma and meningioma occasionally manifest themselves during pregnancy. On the other hand, the opinion that pregnancy has little direct effect upon tumor growth has been expressed from other clinical evidence and experimental work. It is even suggested that in most cases pregnancy may afford a protective mechanism to neoplasia itself (Emge[5]). At this time, there seems to be little evidence to indicate that tumors of the nervous system occur with greater frequency in pregnancy.

The stage of maximum enlargement of the uterus seems to bear a definite relationship to the appearance of symptoms in hemangioma of the spinal cord; and its emptying at delivery with definite improvement. The indictment of vascular changes in or about the tumor as a result of interference with the venous drainage from the spinal canal and its contents may explain the peculiar increase and decrease of symptoms seen in this lesion during pregnancy. In an unrelated study McLennan[9] has recently investigated femoral vein and antecubital vein pressures in pregnancy. He reports that the femoral vein pressures rise slowly during the early part of the 2nd trimester, and exceedingly rapidly once the 3rd trimester is reached, to attain a peak at term. The postpartum state is characterized by a sudden fall to subnormal levels. No significant alterations were seen in the venous pressure in the upper extremity. The abnormal venous pressure is considered to be the consequence of obstruction to venous return by the pregnant uterus. Thus, it is reasonable to assume that the same factor may exercise a marked influence in the venous outflow from the spinal and vertebral vessels to the inferior vena caval system. The fact that in this case the symptoms were temporarily ameliorated during the postpartum period of subnormal or normal femoral vein pressure is very suggestive that venous engorgement in or about the tumor is an important contributory factor.

Vascular phenomena secondary to estrogenic influences may possibly contribute to the symptoms of hemangioma with pregnancy. Vascular spiders and palmar erythema have been seen to appear during pregnancy and to fade rapidly following delivery. The high incidence of vascular spiders has been well known since reported by Corbett in 1914.[3] Palmar erythema has been noted more recently, in 1939 by Feldman.[6] Bean *et al.*,[2] studying over a thousand cases, have confirmed the previous observations and have advanced the hypothesis that the cutaneous vascular changes

were due to high levels of estrogens circulating in the blood for long periods of the pregnancy.

SUMMARY

(1) Spinal cord symptoms and signs in a case of extradural hemangioma became manifest during the last month of pregnancy, improved rapidly during parturition, and completely disappeared after surgical removal.

(2) Exacerbations and remissions in symptoms are considered in relation to mechanical obstruction to venous drainage as a result of an enlarged pregnant uterus, and to possible estrogenic factors giving rise to increased vascularization.

We are indebted to Dr. J. O. Blache, Pathologist, Homer G. Phillips Hospital, for preparing and interpreting the histological sections in this case, and to Dr. Henry G. Schwartz, Professor of Neurological Surgery, and Dr. James L. O'Leary, Professor of Neurology, for their helpful criticisms in preparation of the text.

REFERENCES

1. Balado, M., and Morea, R. Hemangioma extramedular produciendo paraplejias durante el embarazo. *Arch. argent. Neurol.*, 1928, *1:* 345–351.
2. Bean, W. B., Cogswell, R., Dexter, M., and Embick, J. F. Vascular changes of the skin in pregnancy. Vascular spiders and palmar erythema. *Surg. Gynec. Obstet.*, 1949, *88:* 739–752.
3. Corbett, D. [Discussion] *Brit. J. Derm.*, 1914, *26:* 200.
4. Delmas-Marsalet, P. Poussées évolutives gravidiques et image lipiodolée caractéristique des hémangiomes médullaires. *Pr. méd.*, 1941, *49:* 964–965.
5. Emge, L. A. The influence of pregnancy on tumor growth. *Amer. J. Obstet. Gynaec.*, 1934, *28:* 682–697.
6. Feldman, S. A case for diagnosis (palmar eruption due to endocrine disturbance during pregnancy?). *Arch. Derm. Syph. N. Y.*, 1939, *39:* 784–785.
7. Glaser, G. Ein Fall von centralem Angiosarkom des Rückenmarks. *Arch Psychiat. Nervenkr.*, 1885, *16:* 87–100.
8. Guthkelch, A. N. Haemangiomas involving the spinal epidural space. *J. Neurol. Neurosurg. Psychiat.*, 1948, n s. *11:* 199–210.
9. McLennan, C. E. Antecubital and femoral venous pressure in normal and toxemic pregnancy. *Amer. J. Obstet. Gynaec.*, 1943, *45:* 568–591.

## SUBDURAL HYGROMA COMPLICATING MENINGOCOCCIC MENINGITIS

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To the list of complications of meningitis must be added subdural hygroma (hydroma or effusion in the subdural space), which has become prominent only recently as a complication of acute bacterial meningitis.[3,7] The majority of cases of meningitis in which subdural hygromas have been found have been due to *Haemophilus influenzae*. However, cases in which *D. pneumoniae*, *Salmonella sp.*, paracolon bacillus, *Ps. aeruginosa*, and *N. meningitidis* were the etiological agents have also been reported.[7] The relative paucity of information in the literature in regard to subdural hygroma as a complication of meningitis, and the fact that the patient

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in the following case required early surgical treatment with ensuing complete recovery prompted this report.

## CASE REPORT

R.B., a 5-month-old white male infant, was admitted to Children's Hospital, Washington, D.C. (Record #51-1815), on Feb. 11, 1951, because of fever of 8 hours' duration. Past history was negative.

*Examination.* The infant was well-developed, well-nourished, acutely ill, and lethargic, with stiff neck, bulging fontanelle and hyperactive deep reflexes. Temperature was 103.6°F. (39.8°C.). CSF showed 485 cells, glucose 0 mg. per cent, protein 330 mg. per cent and numerous gram negative intracellular and extracellular diplococci on smear; culture yielded *N. meningitidis.* Blood culture yielded *N. meningitidis.* Initial WBC was 3,350; lymphocytes 75 per cent.

*Course.* Chloramphenicol was given intramuscularly (150 mg./kg.) for 6 days and then

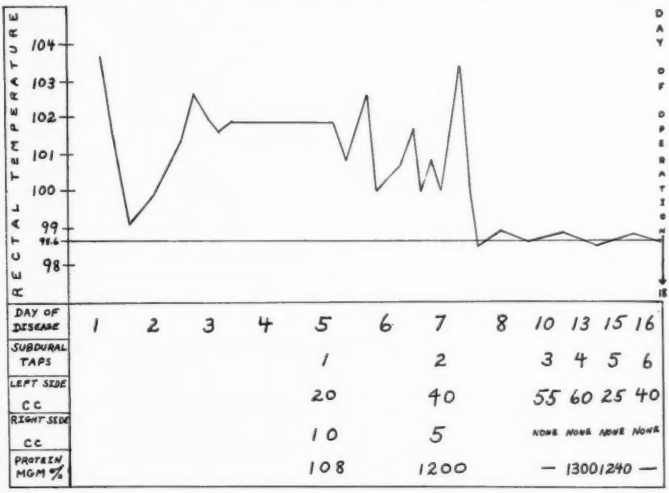


FIG. 1

changed to 250 mg. orally every 6 hours for 6 days. Sulfadiazine was given orally (gr. ii/lb.) for 5 days.

The therapy of choice in acute meningococcic meningitis is the combined use of chloramphenicol and sulfadiazine. Both of these antibiotics have been found to pass the thecal barrier. Initial therapy with these antibiotics is usually parenteral and is changed to oral therapy after subsidence of the acute phase of the illness.[5,6] The chloramphenicol sensitivity test in this case was reported "sensitive to less than 10 mcg./cc."

Temperature dropped to normal in 12 hours after start of therapy but began a gradual rise to 101.8°F. and maintained a plateau at 101.8°F. for 44 hours (Fig. 1). At this point sulfadiazine was discontinued with the possibility of drug fever in mind. Four hours after discontinuance of sulfadiazine the temperature began a drop to normal which was maintained throughout the hospital stay, excepting only a slight postoperative rise.

The fontanelle became normal after the initial spinal puncture but was again bulging on the 4th day of treatment. Spinal puncture at this time had no effect on the fontanelle; the fluid was negative to culture. Blood culture was also negative. Bilateral subdural taps were done. The left side yielded 20 cc. and the right 10 cc. of xanthochromic fluid. The left sul-

dural fluid contained 299 cells, protein 108 mg. per cent, sugar 8 mg. per cent. The right subdural fluid contained 295 cells, protein 137 mg. per cent, sugar 7 mg. per cent. Smear and culture of the fluid from both sides were negative. Five subdural taps were done over the following 11-day period. No fluid was obtained from the right side after the second tap, but increasing amounts were obtained from the left, the protein rising as high as 1300 mg. per cent.

*Operation.* On the 18th day of the illness a left frontoparietal craniotomy was performed. It was felt that the relative chronicity of fluid formation in the left subdural space indicated an organized membrane, removal of which would necessitate bone-flap rather than trephine-drainage. Reflection of the dura disclosed a delicate but relatively tough neomembrane, the appearance of which indicated an inflammatory origin, extending over the entire cerebral hemisphere. Much xanthochromic fluid was retained in the membranous sac. [Culture of this fluid disclosed no growth.] The membrane was teased from its attachment to the dura and arachnoid and removed *in toto* in the fashion applied to the treatment of subdural hematoma.[1,2] The subdural space was irrigated thoroughly, the dura closed, and the wound sutured without drainage.

*Pathologic Diagnosis:* "Granulation tissue."

*Postoperative course* was complicated only by a mild upper respiratory infection, the infant being discharged on March 8, 1951, the 26th day after onset of illness, with no apparent sequelae. Examination 1 month after discharge revealed no evidence of neurological disturbance. The operative area had healed by primary intention. The fontanelle was soft, and the child was alert and playful. There had been no vomiting or retraction of the head, and the appetite was excellent. EEG done on March 27, 1951, 19 days after discharge, was entirely negative. It was apparent that the decision not to investigate the right subdural space because of absence of fluid there after pre-operative taps was justified.

## DISCUSSION

From a survey of the literature it is apparent that the occurrence of collections of subdural fluid in cases of acute bacterial meningitis is not uncommon, especially in infants 1 year of age or under. This complication, however, is being recognized only recently.[3,7] McKay, *et al.*[3] state that the most significant indication of the presence of such fluid is "persistent fever after apparent bacteriologic cure." It is self-evident that bulging of the anterior fontanelle in an infant also should suggest subdural effusion as a possible cause, especially in light of recent experience, if meningitis exists or has existed.

This case represents the early development of a subdural hygroma with rapid recurrence of xanthochromic fluid of high protein content after all cultures were reported negative. It was felt that encapsulated fluid was present and that surgery with removal of the membrane was necessary. Had the fluid decreased in amount to the presumed normal of 0–2 cc. with repeated taps, craniotomy would not have been done. As noted, subsidence of hygroma on the right in this patient after several taps indicated that needle-aspirations had been sufficient to control the contralateral process.

As Ingraham and Matson[1,2] and others[4,8] have indicated, the formation of subdural hygromas or effusions is not uncommon after head injury in infants and adults. The mechanism of pathogenesis—flap-valve tear in the arachnoid of the vertex with admixture of blood and cerebrospinal fluid in the subdural space—is readily visualized when trauma initiates the process. How subdural hygromas with formation of fluid and organization of membranes complicate successfully treated meningitis is more difficult to explain. Complete removal of membranes with freedom for the growing brain to expand thereafter is the surgical procedure of choice, if needle-aspiration of the subdural fluid cannot keep fluid-formation in check.

SUMMARY

1. A case of subdural hygroma with membrane formation complicating meningococcic meningitis has been presented.

2. Early surgical therapy in cases of this type must be strongly considered.

REFERENCES

1. Ingraham, F. D., and Matson, D. D. Subdural hematoma in infancy. *J. Pediat.*, 1944, *24:* 1–37.
2. Ingraham, F. D., and Matson, D. D. Subdural hematoma in infancy. *Advances in Pediatrics*, 1949, *4:* 231–263.
3. McKay, R. J., Jr., Morissette, R. A., Ingraham, F. D., and Matson, D. D. Collections of subdural fluid complicating meningitis due to *Haemophilus influenzae* (Type B). A preliminary report. *New Engl. J. Med.*, 1950, *242:* 20–21.
4. Murphy, J. P. Acute traumatic subdural hygroma. *Yale J. Biol. Med.*, 1950, *22:* 693–702.
5. Ross, S. Personal communication.
6. Ross, S., Preisser, W. G., Orr, W. W., Burke, F. G., and Rice, E. C. Intramuscular administration of chloramphenicol. A preliminary note. *Clin. Proc. Child. Hosp. Wash., D. C.*, 1951, *7:* 61–62.
7. Smith, M. H. D., Dormont, R. E., and Prather, G. W. Subdural effusions complicating bacterial meningitis. *Pediatrics*, 1951, *7:* 34–43.
8. Wycis, H. T. Subdural hygroma. A report of seven cases. *J. Neurosurg.*, 1945, *2:* 340–357.

## INTRACRANIAL ACTINOMYCOSIS

### REPORT OF AN UNUSUAL CASE*

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Actinomycosis of the central nervous system is unusual but not extremely rare. A review of the literature from Ponfick's[11] first case of central nervous system involvement reported in 1882 to Hamby's[5] mention of a case involving the parietal lobe in 1950, indicates that there have been approximately 132 cases reported. It is not felt necessary to refer in detail to all of these cases of actinomycosis with central nervous system involvement because of the excellent reviews of Friedman and Levy[3] in 1937, Cope[1] in 1938, and Lewin and Morgan[8] in 1947. Since 1947, only 3 cases have been reported: one by Jacobson and Cloward,[6] a surgically treated case of cerebral metastatic actinomycosis reported by Schneider and Rand,[14] and the previously mentioned case of Hamby.[5] The case prompting the present report is unusual for two reasons: first, because of its method of spread into the intracranial cavity and secondly, because of the opportunity to follow the course of the disease over a period of several years.

Most of the reports stress the pathological processes evoked in the central nervous system by the organism and secondly, the portal of entry and modes of invasion and dissemination. The pathological processes may be divided into (a) localized, that is, abscess and neoplastic-like collections, and (b) diffuse, that is, meningitis and diffuse extradural involvement. Meningitis with or without concomitant abscess formation is the most common type of central nervous system involvement. The meningitis was almost always basilar and very purulent and there seemed to be a

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predilection for the area around the sella turcica and pituitary gland. Abscesses may be single or multiple and, from a review of the literature, seem quite rare in the temporal lobe. When the organism involves the ventricular wall, especially of the third ventricle, it seems to differ from the usual type of abscess. In these instances, it is almost neoplastic and encapsulated, with central gelatinous material in which typical "sulphur granules" may be found. The lesion may act much like a neoplasm and may even mimic the ball-valve effect of a benign colloid cyst of the third ventricle.

A brief discussion of the various methods of invasion of the central nervous system seems important. Direct extension from the face, jaw, ear, paranasal sinuses and nose is quite common and usually results in basilar meningitis and pachymeningitis. The extension is usually along connective-tissue plains and through foramina at the base of the skull. At times direct extension can occur through bone, as in the case of Lewin and Morgan.[8] The various venous sinuses of the skull may be involved by direct extension. A case of primary actinomycosis of the sphenoid sinus with intracranial extension was reported by Kramer and Som.[7]

Metastatic spread is extremely common and is believed to be almost always by way of the blood stream. In 75 to 80 of the 132 cases, the lesions were unquestionably metastatic. Morrison, Humphrey and Bailey[9] reported a rather unusual case of metastatic disease from a small finger lesion to lung and to brain which was diagnosed during life. Raney[12] reported a case of cerebral metastatic disease in which the primary lesion was in the appendix. Friedman and Levy,[3] as well as Eckhoff,[2] definitely stated that lymphatic spread does not occur; on the other hand, Snoke[16] believed that the lymphatics are important in the spread of the disease.

Primary infection of the central nervous system has been claimed time and again in the literature. The best recent opinion seems to be that primary cerebral actinomycosis does not exist. Zeitlin and Lichtenstein[17] argued strongly against the possibility of primary cerebral disease and affirmed that if careful search is carried out, a primary lesion can always be found elsewhere in the body. In a review of claimed primary cases to 1937, these authors felt that in none of them had the search for a focus elsewhere been adequate. The primary focus may be healed by the time central nervous system involvement becomes apparent. The primary lesion may be almost anywhere. Facial and cervical lesions, as in the case to be presented, are perhaps the most common locations for primary foci. Origin in the lungs, gastrointestinal tract, ears, sinuses and bones of the spinal column is also frequent. A questionable case of primary cerebral actinomycosis seems to be that reported by Orr,[10] which was an actinomycoma of the third ventricle. However, he admitted that a healed hepatic scar may have been the primary source. Rasmussen[13] also told of a case of parietal lobe actinomycotic brain abscess treated with penicillin and streptomycin which was fatal and a careful postmortem examination revealed no primary source. Orr[10] suggested that the portal of entry may be via the perineural spaces around the olfactory nerves. Eckhoff[2] also mentioned the possibility of perineural sheath spread, with special reference to spread from the olfactory bulbs. Schwartz[15] reported the case of a patient operated upon by Dr. Vilray Blair in 1926, in which, at autopsy, the findings greatly resembled those in the case to be presented, with definite indication of perineural spread along branches of the fifth cranial nerve. Finally, from the point of view of direct evidence of perineural spread, the cases of Gonzalez Torres[4] are most important. He studied two museum specimens of cerebral actinomycosis, one with meningitis and a granuloma of the middle fossa,

which was believed to have been definitely caused by spread along perineural spaces of the fifth cranial nerve.

The following case report seems to be of importance in establishing the likelihood of perineural spread from face to middle cranial fossa and also stresses several other interesting points about this rather unusual condition.

## CASE REPORT

Mr. H. T., aged 50, was referred Jan. 15, 1949 by Dr. Frederick T. Hill of Waterville, Maine. He complained of nagging, gnawing pain in the left side of the face. He was employed in section maintenance on a railroad and all his work was outdoors.

*History.* The patient had always been well until July, 1946, when a sudden severe pain occurred in the region of his left mandibular joint. The pain was intermittent but gradually became more severe and constant. Because of it, he had all of his teeth extracted. In February, 1947, a large, tender swelling developed in his left cheek. His physician, Dr. Leon Herring of Winthrop, advised hospitalization. Shortly after admission the mass ruptured spontaneously externally in the cheek, following which he felt somewhat better. However, in 2 months the pain returned; it was equally severe, but there was no swelling.

Dr. Hill first saw the patient in July, 1947. He complained of pain and limitation of motion in the left temporomandibular region. There was a swelling inside his mouth on the left side in the region of the coronoid process. Biopsy resulted in evacuation of pus with relief of symptoms. Pathological diagnosis: Chronic inflammation. He still had some pain, but was able to work. In January, 1948, another tender swelling in the left side of his face was incised and pus was evacuated from what was called a "carbuncle." The swelling subsided but the pain remained and he had increased difficulty in opening his jaw. In June, 1948 there was a large circumscribed mass in the buccal region of the mouth opposite his molar teeth. On pressing this mass, pus was evacuated from a fistulous tract in its center. The parotid gland was not involved. X-ray of the mandible was negative for bone involvement. The mass was removed under local anesthesia by an intra-oral approach. Pathological diagnosis: Tissue resembling a salivary gland tumor. He was markedly relieved and discharged home. In November, 1948 he again began having dull pain in his left cheek. The pain increased, and he was readmitted to Dr. Hill's service in January, 1949. There was scar tissue, with limited motion in the temporomandibular joint. For the most part, the pain was dull but periodically it became severe and lancinating, requiring opiates. There also developed some numbness in the left side of his tongue which the patient felt followed a left mandibular nerve injection with Novocain. At this point, he was referred for neurological study with the possible diagnosis of neuroma of left 5th nerve, mandibular division, or impingement of the nerve by scar tissue.

*Examination,* Jan. 15, 1949. There were paresthesias over the left 3rd division of the 5th nerve. There was an area of point tenderness on the left cheek near the coronoid process. On the inside of the left cheek there was scar tissue, in the center of which was a fistulous opening from which blood and pus could be expressed. Serology was negative. Blood studies were normal but WBC was 11,500. Sedimentation rate was normal. X-rays of the parotid region showed no evidence of stone. X-rays of the skull and chest were normal. EEG was within normal limits.

*Diagnosis.* The initial impression was 5th nerve neuritis, left, secondary to scar tissue. The cause of the scar tissue was undetermined but the possibility of actinomycosis was recorded and apparently forgotten from then on.

*Course.* Section of the 5th nerve was delayed because of the atypical nature of the neuralgia and his continual complaint of numbness following previous injection. The pain required a good deal of medication, and it was therefore decided to give x-ray therapy. He was given 500 r to the left pre-auricular region. There was some change in the character of the pain but no real improvement.

*Operation.* On Feb. 4, 1949, the region of the left gasserian ganglion was explored by the standard subtemporal approach. The landmarks were slightly distorted. When the ganglion was opened, a mass filling Meckel's cave and within the dura over the ganglion was disclosed.

Grossly it appeared neoplastic. Frozen section diagnosis: Acute and chronic infection. The mass was completely removed, and the fibers of the 3rd division were divided.

*Postoperative Course.* He was completely free of pain. The area supplied by the left 3rd division was anesthetic. He was discharged markedly improved Feb. 12, 1949.

*Pathological Diagnosis.* Ganglion and nerve, showing acute inflammatory reaction and fibrosis.

*Subsequent Course.* He was seen Feb. 28, 1949, complaining of numbness but free of severe pain. He returned to work April 15, 1949. He was next seen Jan. 3, 1950. He said that he had been doing well until early December, 1949, when he began having severe pain in his left 2nd division. It was felt that the infectious process had returned and spread. Plans were made for readmission. A bed was not immediately available and he therefore entered the Central Maine General Hospital under the care of Dr. Waldo Clapp. He was given Chloromycetin with rather dramatic improvement and was discharged. However, in 5 days he was readmitted with recurrence of severe pain. At this time he was seen by Dr. William Sweet of Boston, who advised another trial of Chloromycetin and if this failed, reoperation and complete section of the left 5th nerve.

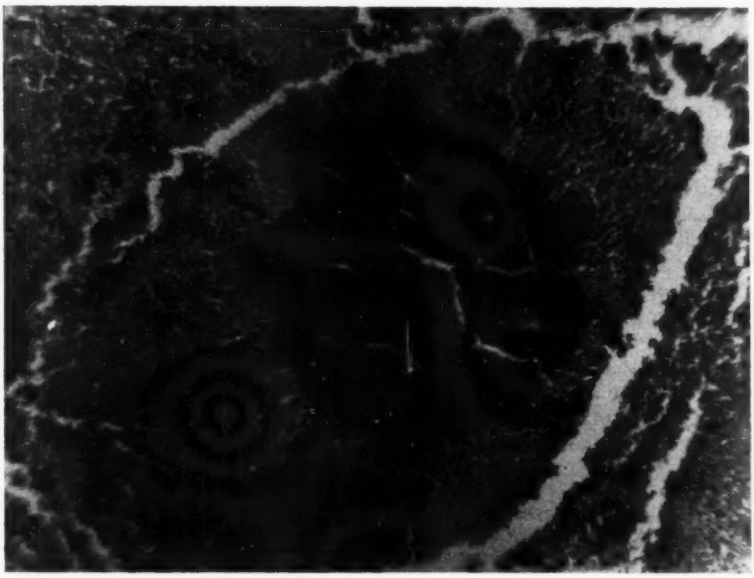

FIG. 1. Section of temporal lobe abscess which shows extensive fibrosis and necrosis. There are many areas of densely packed polymorphonuclear cells, in the midst of which are colonies of radially arranged mycelia with club-shaped ends (sulphur granules).

The second course failed and he was readmitted to the Maine General Hospital Feb. 26, 1950. Neurological findings again were negative except for numbness in the left 3rd division. All laboratory studies, including the WBC, were within normal limits. On Mar. 2, 1950, a second operation on the left ganglion was done by Dr. Robinson L. Bidwell. Difficulty was encountered in retracting the temporal lobe, which was very tense. After adjusting the intratracheal tube, the procedure was somewhat easier. The entire root was sectioned and specimens of the ganglion were removed. Pathological diagnosis: Fibrous tissue with acute and chronic inflammation plus nerves and ganglia, showing acute inflammation.

Postoperatively the vital signs were normal, but he failed to respond. The night of operation, respiratory failure suddenly developed and he died in a few hours.

*Autopsy. Anatomical diagnosis:* Brain abscess, localized, inferior surface and tip of left temporal lobe. *Microscopic diagnosis:* Actinomycosis of brain.

Section through the brain abscess showed extensive fibrosis and necrosis. In these areas, there were many masses of densely packed polymorphonuclear cells, in the midst of which were colonies of radially arranged mycelia with ends that were club-shaped (Fig. 1). Gross and microscopic examination of the lungs, liver, kidneys, spleen and gastro-intestinal tract yielded no evidence of actinomycosis. The cranium showed no evidence of bone destruction, involvement of dural sinus or air sinuses and no extension of the disease through foramina at the base of the skull except that the dura of the temporal lobe and the area of the left gasserian ganglion were scarred and adherent.

## SUMMARY AND CONCLUSIONS

A somewhat unusual case of cerebral actinomycosis is reported.

The literature is briefly reviewed, with special reference to only those reports that seem related to the case presented. The manner of spread and prolonged course of the disease are described.

It is felt that the present case further tends to confirm the opinion that primary cerebral actinomycosis is extremely rare and probably does not exist.

The case also definitely indicates that nerve or perineural spread is one method by which the organism reaches the central nervous system.

Therapy of the condition is still inadequate and almost hopeless. The only bright spots are the case of meningitis reported by Jacobson and Cloward[6] which apparently was cured by massive shotgun use of almost all the newer drugs, and the case of surgical removal of a metastatic actinomycotic brain abscess by Schneider and Rand.[14]

## REFERENCES

1. Cope, Z. Actinomycosis. *London: Oxford Univ. Press*, 1938, xii, 248 pp.
2. Eckhoff, N. L. Actinomycosis of the central nervous system. Report of two cases. *Lancet*, 1941, *1:* 7–8.
3. Friedman, E. D., and Levy, H. H. Actinomycotic infection of the central nervous system. Report of a case and review of the literature. *Internat. Clin.*, 1937, *2:* 36–61.
4. Gonzales Torres, D. M. Cited by Lewin and Morgan.[8]
5. Hamby, W. Personal communication, 1950.
6. Jacobson, J. R., and Cloward, R. B. Actinomycosis of the central nervous system. *J. Amer. med. Ass.*, *1948*, *137:* 769–771.
7. Kramer, R., and Som, M. L. Actinomycosis of the sphenoid with actinomycotic meningitis and brain abscess. *Ann. Otol., etc.*, 1935, *44:* 973–983.
8. Lewin, W., and Morgan, A. D. Actinomycosis of the brain, *J. Neurol. Neurosurg. Psychiat.*, 1947, n.s. *10:* 163–170.
9. Morrison, D. B., Humphrey, A. A., and Bailey, J. E. Actinomycotic meningitis with a primary focus in the finger. Report of a case diagnosed during life. *J. Amer. med. Ass.*, 1938, *110:* 1552–1553.
10. Orr, T. G., Jr. Actinomycoma of the third ventricle, probably primary. *J. Amer. med. Ass.*, 1945, *127:* 757–758.
11. Ponfick, E. Die Actinomykose des Menschen, eine neue Infectionskrankheit auf vergleichend-pathologischer und experimenteller Grundlage geschildert. *Berlin A. Hirschwald*, 1882, 132 pp.
12. Raney, R. Personal communication, 1950.
13. Rasmussen, T. Personal communication, 1950.
14. Schneider, R. C., and Rand, R. W. Actinomycotic brain abscess. Complete excision with recovery. *J. Neurosurg.*, 1949, *6:* 255–259.
15. Schwartz, H. Personal communication, 1950.
16. Snoke, P. O. Actinomycosis. A report of five cases—with four autopsies—two showing involvement of the central nervous system. *Amer. J. med. Sci.*, 1928, n.s. *175:* 69–78.
17. Zeitlin, H., and Lichtenstein, B. W. Actinomycotic abscess of the brain. *Arch. Path.*, 1937, *23:* 58–66.

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